THE
POPULAR SCIENCE
MONTHLY.

MARCH, 1910

INSECTS AND ENTOMOLOGISTS: THEIR RELATIONS TO THE COMMUNITY AT LARGE[1]

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WHEN your president first wrote me, suggesting that I should deliver the popular lecture required by the constitution of this society, he also suggested a subject: "What entomology has done for the world, and its future." The subject is an attractive one; but it required little consideration to decide that within the time at my disposal for preparation and presentation it was impossible for me to do justice to it. The mere compilation of what has been accomplished would require all the time, and I am distinctly doubtful concerning my ability as a prophet. There are no records of any successful ones in my family history and I have never observed any suggestive symptoms in my own case. I therefore secured a compromise on a much less ambitious topic, and find that quite large enough, for, until systematically set down, the importance of insects in their relation to man, direct and indirect, is scarcely appreciated. It is only within the last decade that our conceptions in this matter have become at all clear, and among the public at large extreme haziness is still the dominant condition.

And it was not even easy to determine just what constitutes an entomologist under our present-day methods of specialization, for while not so long ago any person interested in the study of insects at all might be called an entomologist, there are now many students of insects who know nothing at all about them as a whole, but a very great deal about some small, almost or quite invisible part of a single species or group.

[1] Popular lecture delivered at Boston, December 30, 1909, before the Entomological Society of America, its friends and guests.

So we must at the outset classify our students and determine what is really meant by an entomologist:

First of all, we have those individuals who devote their energies to the study of adult specimens only; describing species and genera, revising and monographing groups and, in short, devoting themselves altogether to systematic work. This is essential work, for until species are made known and tagged there is nothing to speak or write about and, no matter how interesting their structure or habits, the information is absolutely useless or unavailable to others, until it can be applied by some definite term to some definite concept.

The systematist then, no matter how little he may know of the insects outside of the dry specimens with which he works, is entitled to be called an entomologist and to have his good deeds recorded here.

Then we have, secondly, those students to whom the systematic position of an insect is a matter of little account; but who are interested in its life history, in its development, in its relation to its surroundings and more or less, perhaps, in its economic importance to man or to some set of men. Without question, these students also are eminently entitled to be considered as entomologists and there is no body of men whose work is of greater importance to the community than those falling under this heading.

In a third category come those who see in the specimen before them a combination of structures of greater or less interest or importance; who care little or nothing for its life history or economic importance, and nothing at all for its systematic position. They need the name of the species only to designate the particular organism that was studied. The work of these students is of the highest possible importance; but they are not entomologists, though their studies may be confined to insect structures. They are anatomists or histologists, depending upon whether they study it grossly, with dissecting needles and low power lenses, or whether they first slice it into sections and then use the high power microscope to look through them. It goes without saying that any member of the first and second division may be a member of the third as well, and I would not be understood as in any way belittling the importance of the work done by these men.

A fourth class is interested in certain species of insects only because of their relation to some other animal or to man, and only in so far as that relation exists. Such are they who study mosquitoes only as intermediate hosts of diseases of man, or bot flies only as parasites of animals. The work done by these students is of intense scientific and practical interest and of the utmost importance to the community, but they are not entomologists, although some of those carrying on this kind of work are entitled to rank as such because of other work done.

And now, what about him who falls under none of my classifica-

tions; the man who uses all his leisure in scouring woods and fields, swamps and running waters, for its wealth of insect life; who works in good weather and bad, for whom the woods at night hold no terrors when in pursuit of specimens? What about the collector? Of a surety he is entitled to rank among the elect, for without him the systematist would have little to work with and the student of insect ecology but a poor basis for his branch of the science. It is the collector who in the past has formed the body of all our entomological societies, and now forms the working majority of most of them. It is the collector upon whom the science rests as a foundation and he is entitled to rank by himself, although aside from this he may and often does belong to one of the other divisions as well.

Now, dropping the entomologist for the moment, let us consider the insects themselves, and here we find their influence extending in every direction; sometimes to our benefit, more often to our injury. Those that affect us injuriously we are able to subdivide into those that attack us directly either as parasites or merely as a source of food supply, and those that prey upon our crops, supplies or farm stock. And even the list of directly injurious forms is not a small one for, to begin with, there are no less than three species of sucking lice that attack the human animal and are confined to him, favoring his head, and other hairy regions, and his clothing when he wears any. It is an interesting matter for reflection that the egg-laying habit of the body-louse is an adaptation that must have required ages to develop and that could not even begin to develop until man wore clothing of some kind.

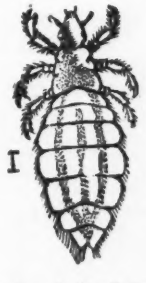

FIG. 1. A head louse.

And wherever man goes wholly or partly unclothed, he shares with other animals the danger of becoming infested with creatures like bots, screw worms and other dipterous maggots, or penetrating insects like jigger fleas and their allies. Man, then, stands in the relation of host to a not inconsiderable number of insects species, only a few of which, however, are really dependent upon him.

But as prey, his usefulness to insects is infinitely greater. In his home a variety of bloodsuckers have established themselves; even in his bed they may be found, and they range from the reasonably sized creatures found in the temperate regions to the infinitely more formidable creatures found in the tropical countries, where the bites often produce unpleasant and even dangerous results.

Where man has hairy pets, like cats and dogs, the fleas that infest them primarily often attack him as a compliment, and in some sections of the world and of own country fleas are not insignificant either in numbers or effects.

Outdoors, Tabanids or horse and other flies in great variety make life miserable in the woods or on the sea-shore, while even in New Jersey an occasional mosquito may yet be met with, ready to demonstrate that he likes you none the less because of any campaigns waged against him—or her.

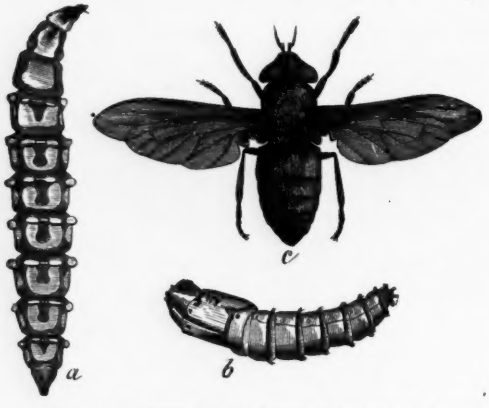

FIG. 2. A horse-fly—*Tabanus atratus; a*, larva; *b*, pupa; *c*, adult; after Riley.

Gnats and midges of various kinds, whether we call them black-flies, punkies or other names, all manifest an affectionate interest in the human visitor to their homes, and I do not mind saying that there have been occasions when I abandoned the field to them and admitted defeat. It is wonderful how well fitted these insects are for their work and how well they understand the use of the tools with which kind nature has provided them!

Some kinds of insects have no grudge against man and as such never bother unless interfered with, but they are quite ready to manifest their displeasure if they are wasps or hornets, or to make it unpleasant in other ways to the ignorant meddler, as in the case of many of our Limacodid larvæ or nettling caterpillars. Sometimes an insect becomes a nuisance quite without intent, as in the case of the caterpillar of the brown-tail, which distributes its hair so liberally that it produces severe irritations and inflammations, as those residents of Massachusetts that have suffered from "brown-tail rash," know to their sorrow.

FIG. 3. The saddle-back caterpillar, *a*, from above, and *b*, from side; after Riley.

And this brings me, naturally, to the consideration of those forms that are troublesome or even dangerous to man because they are agencies in the transmission of diseases, either as carriers or as intermediate hosts. Note that I use two terms; *carriers* and *intermediate* hosts, because there is a vast difference between them. Carriers are such insects as merely pick up by accident disease "germs"—to use a current expression—and transport them to another place where they may or may not

find a suitable medium to propagate, and where they may or may not be in position to get into the proper portion of the human animal. Almost any sort of insect may be a carrier, although there are some few peculiarly adapted for the purpose, and such a carrier may be the transmitting agent for a variety of diseases: it is not itself affected by any, and is in no sense a fellow sufferer.

It is different in the case of intermediate hosts; here the insect itself harbors one stage of the morbific organism and is itself a sufferer from one form of the disease. Its power of transmission is strictly limited and is restricted to one disease alone.

The best known and most abundant of the germ carriers is the common house-fly more recently called "typhoid fly." Now it un-

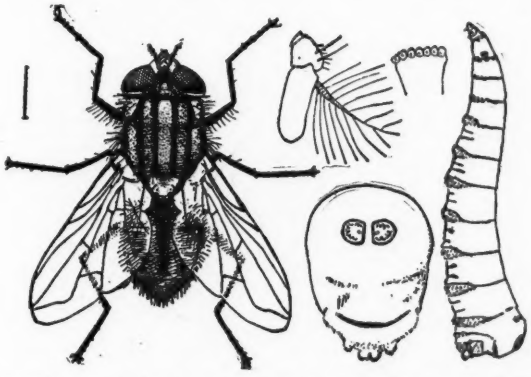

FIG. 4. The house-fly, with its larva and details of structure; after Howard, U. S. Department of Agriculture.

doubtedly is *a* typhoid fly, but it is only one of several species that may be equally effective, and it is by no means a carrier of typhoid germs only. Its habits are such that it may be a transmitting agent for any intestinal disease and for many of the pulmonary and bronchial troubles as well. In a typhus or cholera epidemic it is a "cholera" or "typhus fly" and to call it the "typhoid fly" gives an unfounded suggestion of definite relationship between disease and insect.

But it certainly is marvelously well adapted as a carrying agent. Its omnivorous feeding habits, its persistence in seeking entrance at places where savory or other pungent odors attract it, and its foot and mouth structure make a combination difficult to equal. The pulvilli of the feet with their numerous minute hooked hairs are ideal collectors of microorganisms, and the lobed, lip-like mouth structure, with its array of pseudo-trachea for surface scraping, can hardly be surpassed in effectiveness. No doubt the house-fly is a danger of the first order, and there is no economic problem now before the sanitarian, of more importance than the elimination of this pest. That it can be done there is no doubt, and that in time it will be done is equally certain.

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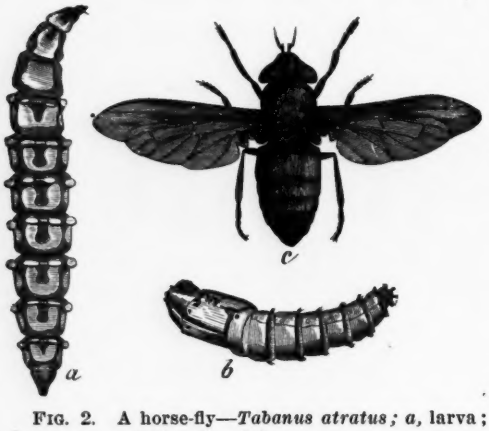

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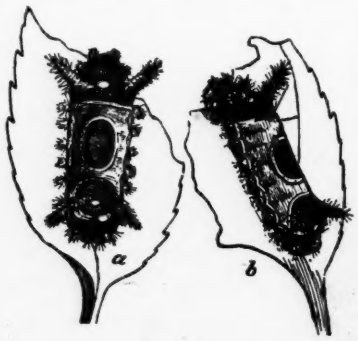

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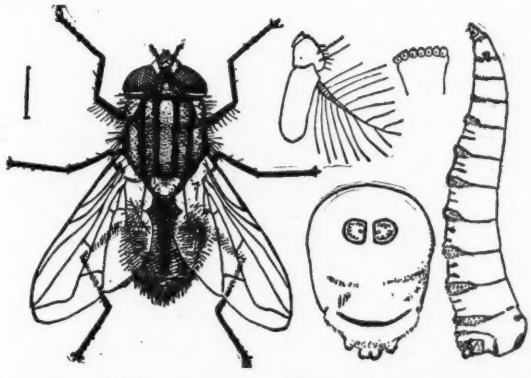

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There are numerous other flies and insects that serve as carriers, and there are numerous diseases due to more or less uncleanly habits, that are carried by insects; but the process is so simple and direct that it offers little of scientific interest.

Much more complicated is that transmission of disease in which the insects act as intermediate hosts, and here again the members of the order Diptera lead the way. We assume that man is highest in the scale of vertebrate development, and it is no part of my thesis to dispute this. It is equally assumed that the Diptera are most highly specialized in their development among the insects, and it is significant that the association of humanity with these flies has been so close and

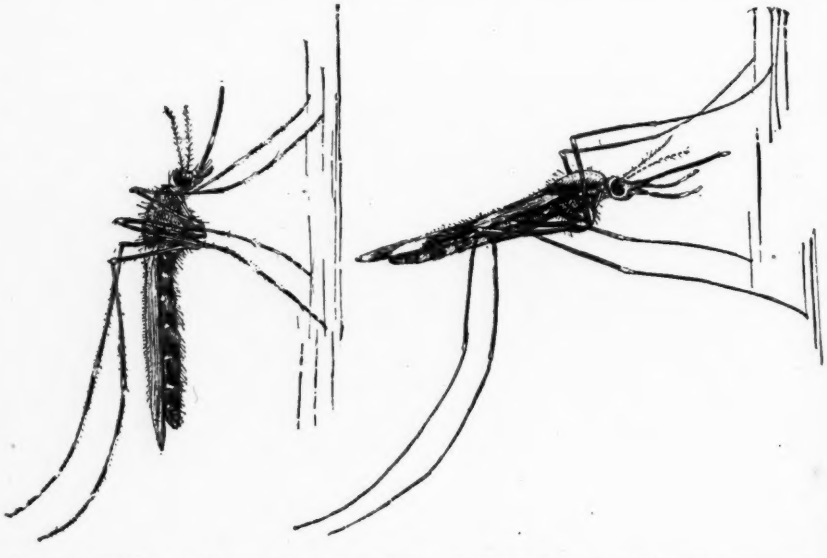

FIG. 5. Resting position of *Culex*—at left; of *Anopheles*—at right; after Howard, U. S. Department of Agriculture.

so long continued that it has been possible for a common parasite to develop whose continuance depends absolutely upon the intimate association of the two.

If all insects were eliminated absolutely, typhoid, cholera and associated diseases might still continue to plague mankind; but eliminate *Stegomyia calopus* and yellow fever would be equally eliminated, because without that particular species the parasite causing the disease would find it impossible to continue its existence. Not that we know very much about the "germ" of yellow fever, and its life-cycle is largely guess-work; but we do know enough, from direct observation and experiment, to warrant the statements that I have just made.

It is different in the case of malerial fevers and their association with certain species of Anopheles. Here we do know from direct

observation the entire life-cycle of the parastic organism from the time it enters the circulation through the beak of the mosquito until it reaches its limit of growth in the human body. We have observed the blasts and sporozoits entering a red blood corpuscle; we have observed the gradual growth in this corpuscle; we have followed the gradual breaking down of the cells and have observed their rupture and the discharging spores. The development of the gametes has been observed; the flagellation and conjugation of the micro- and macro-gamete and the development in the Anopheline stomach from vermicule to zygote. All this has been demonstrated, and so little guess-work is there about it that the elimination of Anopheles breeding places is now the first step in dealing with an outbreak of real malarial trouble.

The relationship between rats, fleas and plague has also been practically established, and elimination of the disease in man is sought by the destruction of rats. I have already mentioned, in another connection, that the cat and dog flea would, when opportunity served,

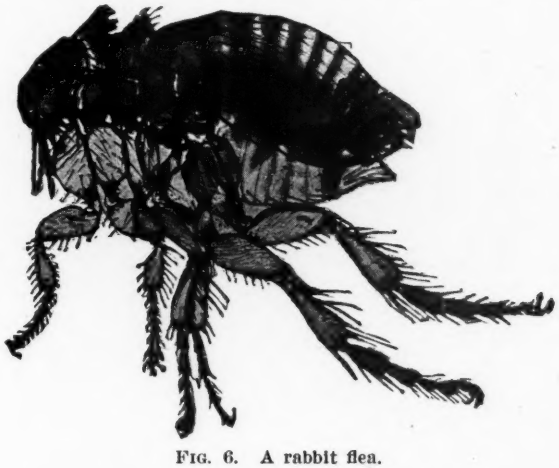

FIG. 6. A rabbit flea.

bite human beings; the statement may be made more generally that almost any flea will, when there is occasion, bite almost any warm-blooded animal upon which it finds its way. So the fleas upon plague-stricken rats, leaving their natural hosts, may and do infest men instead of other rats when men herd where rats abound.

In more torrid or tropical countries insect-borne diseases are more numerous than in our more temperate clime, and there the mosquitoes, bearing a much greater variety of fevers, also transmit organisms of much higher character than "germs." Filariasis is a disease caused by minute thread-worms or *filaria,* and these also require the mosquito as an intermediate host to complete their development.

In recent years the records of studies made of certain tropical diseases have been largely records of studies in insect transmission of

disease; and the studies made on insects, by physicians, have been as important as those made on the afflicted patient.

The identification of a species of Glossina or tsetse fly as an agent in the spread and transmission of the "sleeping sickness" is one of the more recent accomplishments in this direction, and opens a way for dealing with this plague that has practically depopulated great areas in Africa.

This seems like a series of heavy indictments against a lot of insignificant creatures whom, heretofore, we have deemed ourselves justified in ignoring. But the case has been understated rather than otherwise, and it is time that we recognized insects as among the most dangerous enemies to man from the sanitary standpoint.

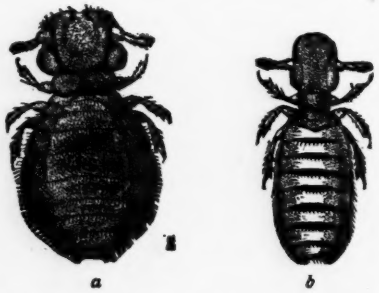

FIG. 7. Types of Mallophaga or biting lice.

Let me put it in a somewhat different way: could we at a blow eliminate all the members of the single order Diptera—including the fleas—we should at the same time absolutely eliminate malaria, yellow fever, dengue, jungle and several other kinds of tropical fevers, the bubonic plague, sleeping sickness, filariasis, several forms of eye diseases, certain ulcerating sores in tropical countries, and we should reduce to a minimum enteric fevers of all kinds, lessen the death rate from tuberculosis and pulmonary troubles, and probably modify or lessen leprosy and kindred diseases.

But this is not all our plaint; for besides attacking man directly in his bodily health and comfort, they attack his domestic and other animals and lessen their value if they do not absolutely destroy them.

Every one of our domestic animals and all our feathered friends of the barnyard are infested by lice—biting and sucking and some of them harbor several species. All of them are well adapted in form to the conditions under which they live; and even the hog, which is not usually thought of as a hairy animal, has a species that manages to move about as freely as need be among the bristles. Naturally, animals so infested can not do their best for their masters; they become mangy in appearance, do not grow well, the fowls lessen in egg production and the cows in milk.

To the dairyman, flies—comprehensively speaking—are nuisances from all points of view. In the pasture Tabanids in great variety get after them; in the stable Stomoxys is always on hand. Occasionally the fauna of one country contributes a pest to that of another, as was the case when the so-called horn-fly was introduced about twenty years

ago from Mediterranean Europe and rapidly spread throughout the United States and Canada.

Buffalo gnats and similar species make certain sections of the Mississippi Valley region almost uninhabitable for cattle at times, and dairying in some places is barred because of the abundance of mosquitoes. These are all external attacks which reduce the condition of the creature attacked because of the irritation, pain or actual loss of blood.

There are others that are more truly parasitic, like the bots. Wherever sheep are raised in numbers the herders have their troubles with the species that gets into the nasal passages, causing blind staggers and often death. Cattle are infested by species that lodge under the skin,

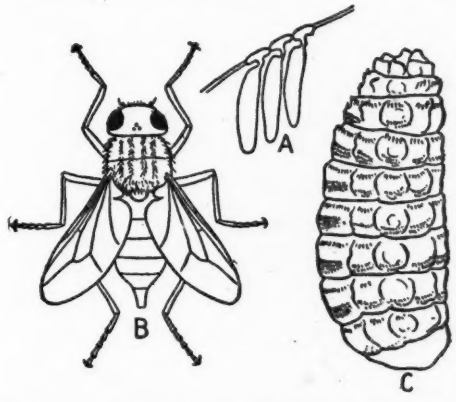

FIG. 8. The ox bot, *Hypoderma lineata; a,* eggs; *b,* fly; *c,* larva.

forming suppurating sores along the back. These reduce the condition of the animal and materially lessen the value of the skin. Horsemen know to their sorrow the species that fixes on the walls of the stomach, often in such numbers as to kill the animal. To realize the amount of suffering caused to their hosts by these insects and others with similar habits is almost impossible. To estimate the money loss caused to man has been attempted and the figures run to astounding sums.

But the end is not even yet, for these same animals often suffer from diseases similar to those of man and like them transmissible through or carried by insects. Ticks are not insects, but the economic entomologist is often expected to deal with them, hence we may just mention the cattle tick in connection with Texas fever, which has destroyed and still destroys its thousands and causes enormous money losses.

Many of our birds suffer from maladies similar to malaria, caused by a Proteosoma, and even the common and ever vociferous sparrow is not exempt. These species of Proteosoma find their intermediate hosts in certain species of *Culex* or whatever the present equivalent

of that generic term may be. Some of these diseases have been carefully worked out, but how many more remain of which we know nothing as yet, I would not even dare to guess.

The effect of the tsetse fly or its bite on horses in South Africa has been long known, but just how that effect is produced is a matter of more recent knowledge. We know now that the disease is produced by Trypanosomes carried by the flies, and this information has opened the way to intelligent treatment.

Here again, be it noted, the order Diptera contributes the bulk of the dangerous species to the mammalian types, and to our horses,

FIG. 9. A silver-fish, *Lepisma* sp.; from Howard, U. S. Department of Agriculture.

cattle and sheep, the elimination of all flies would be as great a boon as to man himself.

Heretofore I have spoken only of insects that either attack or influence the health of man or other animals. But there are numerous others that live with him and are messmates, sharing in the produce that he has stored for his own use, and in this work members of almost every insect order are concerned.

The Thysanura are represented by various species of Lepisma or

silver-fishes, and sometimes by spring-tails and bristle-tails where produce is stored in damp places.

The Neuroptera have quite a variety of forms, ranging from the Psocidæ which the housewife usually regards with a disgust intended for parasites of similar form, to the Termites or white ants whose work is noted more frequently than the insects themselves.

Among the Orthoptera, the voice of the cricket on the hearth calls up only pleasant association; but the appearance of roaches in kitchen and pantries arouses feelings of quite a different character. And roaches of many varieties are found in human habitations throughout the world.

As to the Hemiptera or true bugs, they have been already referred to as direct feeders or parasites upon man himself or his domestic animals. They do not add to their sins attacks on his supplies.

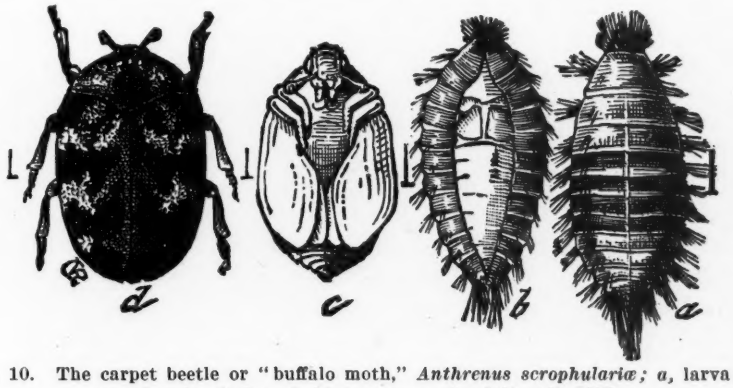

FIG. 10. The carpet beetle or "buffalo moth," *Anthrenus scrophulariæ; a,* larva; *b,* pupa forming in larval skin; *c,* pupa; *d,* adult; after Riley.

The Coleoptera or beetles contain numerous messmates and some that do not even confine themselves to his stores. The carpet beetles feed upon his supplies of woolens, whether on the floors or on the shelves, and occasionally they get into the feathers of his pillow. But these are minor troubles compared with those that arise when the feeding is on the feathers of the madam's hat or the fur of her winter coat. Similar species get into our closets and pantries to feed upon the meat supplies, and occasionally we find them already established in provisions received from the packing houses, so that similar species occur the world around. Our grain, flour and meal supplies furnish homes to more kinds of species than the ordinary householder cares to consider, and nowhere does neglect or lack of cleanliness produce quicker infestation than in the pantry where our grain products are stored. Our lentils, peas, beans and other legumes are attractive to a variety of "weevils," especially in barns and granaries.

Even the den of the master of the house is invaded—if he is master and has a den—and in his supply of cigars and cigarettes the cigarette

beetle and its larvæ hold forth—scarcely improving the flavor of the tobacco for smoking.

Among the Lepidoptera we find valiant aids to the beetles in destructive work on stored products. There are various kinds of meal-

FIG. 11. The cigarette beetle; *a*, from side; *b*, from above; *c*, larva.

moths, feeding on whole or prepared grains, and some of these, like the Mediterranean flour moth, cause serious troubles in mills. The well-known "Angoumois grain moth" not infrequently ruins entire crops of wheat for milling purposes, and in barns and granaries breeds continuously. Dried fruits are attacked by similar species and indeed scarcely anything in the pantry is exempt from the small caterpillars which usually live in silken tubes of their own construction.

And then there are the clothes and carpet moths which cause troubles of their own and are sources of much worry and expense to a part of the population not ordinarily interested in entomological matters. Incidentally they are sources of income to others who thrive on

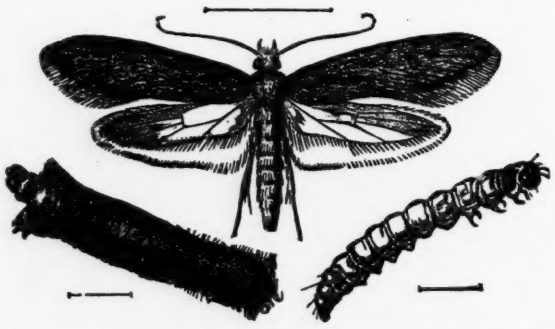

FIG. 12. A clothes-moth, with its larva free and in a case; from the Division of Entomology, U. S. Department of Agriculture.

selling compounds more or less effective in protecting fabrics against the ravages of the "moths."

In the order Hymenoptera there are comparatively few species, confined practically to one series of families—the ants—that cause trouble in our households. But these, where they do occur, may exceed a combination of all the others in the annoyance and positive

injury that they cause. There are several native forms, large and small, red and black, that are frequently pestiferous, and within the few years last past we have acquired another, the "Argentine Ant," which, as is customary with introduced pests, does more harm within its present range than all the native kinds combined.

Again we have reached the Diptera or flies; but this time there is very little fault to find, for those species, other than the pests already mentioned, that do come into our houses, do so mostly as scavengers.

And there is yet another heading under which we have to consider insects in their effect upon man, and that is in the light of pests on the crops which are grown by him. A very large percentage of all insects are vegetable feeders and, naturally enough, when large areas are planted to one crop, so as to eliminate for the insect the problem of food supply, and cultural methods lessen their natural enemies, these vegetable feeders flourish out of all proportion to their normal natural limitations. The result is that a considerable percentage of the crop is destroyed, and most of the destroyed percentage represents the farmers' profit. That is to say, suppose it costs $5.00 to cultivate, plant, harvest and thresh an acre of wheat, and the harvest sets for a 15 bushel crop. With wheat at $1.00 per bushel at the station, the farmer might count on a profit of $10.00 per acre. But if in spring chinch-bug attack reduces the yield by 5 bushels, and the wheat-head army worm destroys 3 bushels more, the net return is reduced to $2.00 per acre, which is not living wage to the owner.

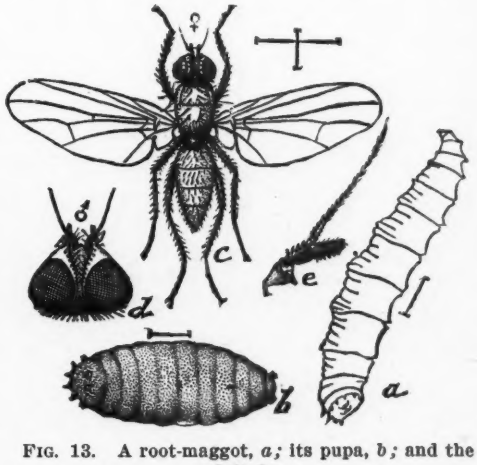

FIG. 13. A root-maggot, *a*; its pupa, *b*; and the adult fly, *c*.

That this sort of reduction occurs with discouraging frequency on many sorts of crops throughout our country, is within the experience of every economic entomologist, and the total calculated loss per annum from insect attack in the United States alone amounts to $1,500,000,000. Surely a terrific tax to pay and one which is not paid without protest.

Not only is practically every crop attacked, but every portion of the plants may be infested. There are maggots that burrow into the roots of vegetables; borers that live in the roots of trees, shrubs and even meadow plants, and wire-worms and grubs that eat off the rootlets of grasses, strawberries and the like. Potatoes are gnawed under-

ground by a variety of insects, and not a tuber nor a bulb escapes infestation.

The stems of herbaceous plants and shrubs and the trunks and branches of trees harbor borers without number and belonging to several orders. Vigorous growing vines like those of cucurbits may harbor several borers in a single stem, while even a wheat straw affords ample accommodation for several species, from the minute joint-worms to the caterpillars of owlet moths.

Fruit and other trees are attacked even in the nursery, and many a seedling never gets beyond the earliest stage of development. The temptation is great to enlarge on these points; but the difficulty would then be to find a stopping place. It must suffice to say that there is no part of a plant from the tip above to the rootlet below ground that

FIG. 14. The San José Scale as it appears on an infested shoot; from the Virginia Experiment Station.

may not be inhabited by a borer. Nor, on the other hand, is there a part of the outside of the plant above ground that may not be infested by scales or plant-lice.

Not so many years ago the Pacific Coast feared for its fruit industry because of the Cottony Cushion Scale, an imported pest. Still more recently the eastern United States was invaded by the San José Scale, another imported species which is responsible for more legislation, more organization, more expenditure of money and a greater revolution in methods of fruit growing, than any insect in history. No

one who has not been in this fight from the beginning and who has not seen the changes in development, can really appreciate what has happened in the last decade. Incidentally, this insect has made more positions for entomologists and has stimulated more interest in entomological work than all other species combined; in which respects it may not be considered an unmitigated pest.

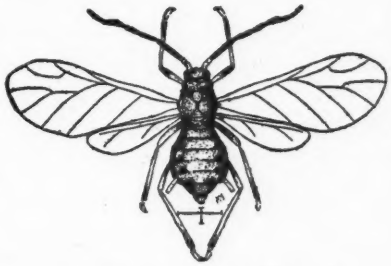

FIG. 15. A winged plant-louse.

As for plant-lice, their name is literally legion and their study is only begun. We find their eggs in winter and the insects themselves throughout the year. With the beginning of plant-growth the Aphids also begin development and the character of the infestation is as various as the plants or parts of plants attacked. They are not even confined to the overground parts of the plant, but may be on the roots as well; either permanently or in an alternate stage. It is just allowable to mention the grape Phylloxera as a species that does all its real injury in the subterranean stage, and to record that this is one of the few contributions that America has made to European agriculture, in return for the many that we have received.

The host of other plant bugs that suck the juices of vegetation can only be hinted at. Mention must be made, however, of the chinch-bug, which in the middle west has been the subject of more careful study and experiment, and has done, perhaps, more wide-spread damage than any other of its ordinal allies.

As to feeders on foliage, there seems no end to them and they are of all orders. Nor are their injuries of recent notice. The plague of locusts which devoured all crops was one of those visited upon Egypt in the days of Moses, and similar plagues of locusts exist to this day in African countries. They have not been unknown in the United States in years past and it is not yet safe to say that there will be no more.

Gypsy and brown-tail moths afford excellent illustrations of the expense that caterpillars may impose on a community, for they have cost Massachusetts alone not less than $2,000,000 directly and indirectly, while the general government has already spent more than half a million.

No part of a plant being free from insect attack, the fruit and seeds should also be infested, and so we find it. Codling Moth and Plum Curculio are terms known to horticulturists throughout the country, while cotton-boll weevils have more recently taken a prominent position in our southern states.

I trust that I have succeeded in convincing my audience of the important part that insects play in the community, and how vitally they affect man in his life, his health and his pocket. I might add to emphasize this still more, that were all natural checks removed from plant-feeding insects for two successive years, not a green thing would be left on the face of the earth; and that with the same checks removed from the forms parasitic and predatory on the higher animals, the third year would probably see the end of all vertebrate terrestrial life.

The questions will naturally arise—is there no brighter side to this subject? Are not insects of some use, and do we not derive some benefit or advantage from them?

Both of these questions are answerable in the affirmative, for insects are distinctly and importantly useful to man both directly and indirectly, altogether aside from the fact that parasitic and predatory species materially reduce the amount of injury that would otherwise be caused by those already mentioned.

Leaders among the directly beneficial species are the honey-bees and silk worms. Bee products, wax and honey, amount to millions of dol-

FIG. 16. Honey bee.

FIG. 17. A burying beetle, *Necrophorus* sp.

lars annually, and there is no more attractive food than good honey —a matter that is much more appreciated in continental Europe, where honey is a usual part of breakfast, than in the United States, where it is rarely seen on our tables at any meal. Bees-wax is, of course, an important commercial product, although its place for many purposes has been usurped by the cheaper paraffin.

As for silks, I would not dare to estimate the amount of money invested in them annually. The silk worm makes up in value for much of the injury caused by other caterpillars, and it would be well sometimes for our grand ladies in rustling garments to realize that they owe a large percentage of their exterior magnificence to a nasty, inconspicuous caterpillar.

Before the development of the aniline dyes there was no more beautiful scarlet than that obtained from the cochineal insect, a miserable coccid, allied to some of our destructive mealy bugs. As a pigment it produced a beautiful carmine, and this may make us look more leniently upon creatures like the cottony cushion and San José scales. Several of our common soft scales, notably that huge creature that infests the tulip tree, give a purplish extract in alcohol, and so do some of the Lachnid plant lice; but they will hardly be considered now-a-days as a source of coloring materials.

Insects figure to some extent in the pharmacopœia, although not so much now as they did in days gone by. That powdered roaches had medicinal qualities was known to the ancients, and I believe that tinctures and extracts of these insects are still obtainable. Spanish flies or cantharides have a well deserved reputation for blistering properties and have been used to promote the growth of hair. They have also been made into extracts and tinctures, and used internally for a variety of troubles.

Bees produce an acid that is useful in some rheumatic affections, and it is asserted that the simplest effective method of application is to allow the bee itself to administer the remedy directly to the affected part. Incidentally, by this method the patient gets back at the operating physician, for whether the patient is benefited or not, the administrator dies as the result of the application.

But decoctions and other preparations of insect species are no longer so much thought of as in days gone by, and we now run to sanitation and other preventive measures, to serums and antitoxins, to antiseptics and to coal-tar products, so I need hardly claim very much more for insects under this head.

I might mention that insects as food material are not unknown, and while I have already mentioned locusts as a plague, I might add in mitigation that they also serve as an important article of food for the natives in the countries where they occur in such numbers. Wood-boring larvæ and even insect eggs have been and are even yet eaten; but their value in these respects can hardly be deemed sufficiently great to give them a favorable standing in our present communities.

Indirectly valuable to man are a long series of species that act as scavengers, reducing dead animal and vegetable matter to its inorganic compounds, and another series that serves as an aid to plant propagation. The former need little attention because man can do scavenger work much better and quicker himself; but in the work of plant pollination the importance of insect work is scarcely appreciated by the public at large.

Numerous plants depend absolutely upon insects for continued existence, and there are all stages of dependence from those where the

plant depends on one species only to those for whom any insect that can carry pollen at all will serve. An illustration of a dependent plant is the Yucca which is visited by a little white moth, a Pronuba, which proceeds in its work as deliberately and purposefully as if it realized the importance of every step in the process. Another of still greater interest is that of the edible Smyrna fig, which depends upon Blastophaga for its fruit development. It is a case where the establishment of a horticultural interest depended upon the possibility of introducing with the fruit its specific pollinator as well.

The relation of bumble-bees to red clover is so well understood now that it is not really necessary to do more than mention it, and in general, the most effective pollinators are found among the bees, because they, more than any other insects, are structurally adapted for the gathering and transportation of pollen. Not only are the mouth structures adapted for getting deep into the flower cups but the hairy covering itself is modified so that it holds the grains dislodged as the insect moves among them.

To be sure butterflies and moths are also of use, and the butterfly tongue is well adapted for its purpose of reaching down and lapping nectar from concealed nectaries. Some of these tongues indeed are so developed as to permit the insects to feed while on the wing and to get into depths beyond the reach of less favored species.

(To be concluded)

THE SECOND LAW OF THERMODYNAMICS: ITS BASIS IN INTUITION AND COMMON SENSE[1]

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IT is the object of this article to give a simple account of that fundamental principle in physics which is known as the second law of thermodynamics. No generalization of modern physics is of greater importance, not even the principle of the conservation of energy, and no generalization of modern physics is based upon such deeply seated and such widely diffused human intuitions. It is the purpose of this article to give a sharp characterization to this widely diffused intuition.

Thermal Equilibrium

The most important single fact in connection with the study of the phenomena of heat is that a substance settles to a quiescent state in which there is no tendency to further change of any kind when it is left to itself and shielded from all outside disturbing influences. This quiescent state is called a state of thermal equilibrium. For example, the various objects in a closed room settle to thermal equilibrium; when a piece of red-hot iron is thrown into a pail of water, the mixture, at first turbulent, becomes more and more quiet and finally reaches a state of thermal equilibrium. A number of bodies which have settled to a common state of thermal equilibrium are said to have the same temperature. Thus a number of bodies left together in a closed room have the same temperature.

Atomics and Thermodynamics

In nearly every branch of physical science there are two more or less distinct modes of attack, namely, (*a*) a mode of attack in which the effort is made to develop conceptions of the physical processes of nature, and (*b*) a mode of attack in which the attempt is made to correlate phenomena on the basis of sensible things, things that can be seen and measured. In the theory of heat the first mode is represented by the application of the atomic theory to the study of heat phenomena, and the second mode is represented by what is called thermodynamics. In the first case one tries to imagine the nature of such processes as the melting of ice or the burning of coal, and in the second case one is content to measure the amount of heat absorbed or given off and to

[1] The substance of this article will be incorporated in Franklin and MacNutt's "Elementary Theory of Heat," which is now in preparation.

study the physical properties of the substance before and after the change has taken place.

The Atomic Theory of Heat.—The theory of heat properly includes the whole of chemistry, and every student of elementary chemistry is familiar with the use of the atomic theory in enabling one to form clear ideas of chemical processes. For example, the burning of hydrogen is thought of as the joining together of atoms of hydrogen and oxygen to form molecules of water vapor. The atomic theory is also of use in giving one clear ideas of the physical properties of substances. Thus, a gas is supposed to consist of a great number of particles in violent to-and-fro motion, and the gas exerts a pressure against the walls of the containing vessel because of the bombardment of the walls by the rapidly moving molecules of the gas. In addition to these two highly developed branches of the atomic theory (chemistry and the theory of gases), the atomic theory has been applied in a more or less vague but very useful way in the study of a great variety of heat phenomena as exemplified in the following quotation from Tyndall's "Heat a Mode of Motion."

> When a hammer strikes a piece of lead the motion of the hammer appears to be entirely lost. Indeed in the early days it was supposed that what we now call the energy of the hammer was destroyed. But there is no loss. The motion of the massive hammer is transformed into molecular motion in the lead, and here our imagination must help us. In a solid body, although the force of cohesion holds the atoms together, the atoms are supposed, nevertheless, to vibrate within certain limits, and the greater the amount of mechanical action invested in the body by percussion, compression, or friction, the greater will be the rapidity and the wider the amplitude of the atomic oscillations.[2]

Thermodynamics.—To understand the essential features of the science of thermodynamics it is necessary to revert to the discussion of work and energy. Whenever a substance gives up energy which it has in store the substance always undergoes change. Thus, the fuel which supplies the energy to a steam engine and the food which supplies the energy to a horse undergo a chemical change; the steam which carries the energy of the fuel from a boiler to a steam engine cools off or undergoes a thermal change when it gives up its energy to the engine; a clock spring changes its shape as it gives up its energy in driving a clock; an elevated store of water changes its position as it gives its energy to a water wheel; the heavy flywheel of a steam engine does the work of the engine for a few moments after the steam is shut off and the fly-wheel changes its velocity as it gives up its energy.

In mechanics the theory of energy is discussed in connection with mechanical changes only, thermal and chemical changes being carefully ignored, and in taking up the study of thermal and chemical

[2] Tyndall goes on to explain in a general way the difference in the constitution of solids, liquids and gases. See "Heat: A Mode of Motion," pp. 115–119.

changes it is important to understand that our study is not to be concerned with thermal and chemical actions themselves, but with their results. The actions themselves are as a rule extremely complicated. Thus the details of behavior of the coal and air in a furnace are hopelessly complicated! The important practical thing,[3] however, is the amount of steam that can be produced by a pound of coal, and this depends upon (1) the condition of the water from which the steam is made, that is, whether the water is hot or cold to start with, (2) the condition of the air and of the coal which are to combine in the furnace, (3) the pressure and temperature of the steam which is to be produced, and (4) the condition of the flue gases as they enter the chimney. That is to say, the only things which it is necessary to consider are things which relate to quiescent substances. A quiescent substance may be said to be in a standing condition or state and the whole subject of heat (thermodynamics) may be said to refer to changes of state, that is, to changes from one quiescent condition to another quiescent condition without regard to the details of action which lead from one quiescent condition to the other.

Mechanical Energy and Heat Energy

In studying thermal and chemical changes we have to do with a new kind of energy. The gravitational energy of an elevated store of water can be wholly converted into mechanical work, the energy of two electrically charged bodies can be wholly converted into mechanical work (for example, by allowing the charged bodies to move towards each other), the kinetic energy of a moving car can be wholly converted into mechanical work, and so on. On the other hand, the energy of the hot steam which enters a steam engine from a boiler can not be wholly converted into mechanical work. Any store of energy which can be wholly converted into mechanical work may be called mechanical energy. The energy of the hot steam which enters a steam engine from a boiler is called heat energy.[4]

In the attempt to exclude all thermal changes from the purely mechanical discussion of energy one is confronted by the fact that friction (with its accompanying thermal changes) is always in evidence

[3] This practical matter is exactly of the same character as any purely scientific matter involving the application of thermodynamics. It is always a question concerning the correlation of measurable and sensible things.

[4] The important difference between mechanical energy and heat energy, namely, that one can be wholly converted into mechanical work whereas the other can not, may be clearly understood in terms of the atomic theory. Every particle of a moving car travels in the same direction and all of the particles work together to produce mechanical effect when the car is stopped; the molecules of hot steam, however, fly to and fro in every direction, and no method can be devised whereby the whole of the energy of the molecules of hot steam can be used to produce mechanical effect.

everywhere. In every actual case of motion the moving bodies are subject to friction and to collision, their energy is dissipated and they come to rest. This dissipation of energy is always accompanied by the generation of heat, and experience shows that the amount of heat generated is equivalent to the energy dissipated (first law of thermodynamics). It is important to understand that the term dissipation of energy refers to the conversion of mechanical energy into heat by friction or collision.[5] Thus energy is dissipated in the bearing of a rotating shaft, energy is dissipated when a hammer strikes a nail, and so on. The atomic theory enables one to form a clear idea of the dissipation of energy. Thus, the energy of the regular motion of a hammer is converted into energy of irregular molecular motion when the hammer strikes a nail.

It is worth while to give a statement of the first law of thermodynamics reduced to its simplest terms. A given substance is heated by the dissipation of work and brought back to its initial state by being cooled by contact with another (cooler) substance B. Then, if the loss of heat to surrounding bodies is carefully avoided, the thermal effect produced in substance B is exactly the same as would be produced in it if it had been heated directly by the dissipation of the original amount of work. Therefore a substance which is heated by the dissipation of work stores something which is equivalent to the work and which is called heat.

Gay Lussac's Law and the Air Thermometer.—When a number of closed vessels containing different gases at the same pressure are carried from a cool cellar, for example, to a warm room, they all suffer the same rise of temperature, and all of the gases show the same increase of pressure. That is to say, all gases follow the same law of increase of pressure with increase of temperature, the volumes of the containing vessels being constant. This fact was discovered by Gay Lussac and it is called Gay Lussac's Law. This law affords a convenient basis for the definition of temperature ratios, convenient because not dependent upon any particular gas. The ratio of two temperatures (provisionally defined) is the ratio of the pressures of a constant volume of gas at the respective temperatures. That is, if p and p' are pressures of a constant volume of a gas at temperatures T and T', respectively, then we have by definition

$$T/T' = p/p' \qquad (1)$$

The air thermometer is a device for measuring the ratio of two temperatures by observing the pressures of a constant volume of dry air at the respective temperatures.

[5] Energy is also dissipated in a wire in which an electric current flows.

Simple Knowledge Assumed

A great deal of simple every-day knowledge is always taken for granted in a treatise on thermodynamics. It is stated above that the important things in connection with the generation of steam in a boiler by the burning of coal are (*a*) the temperature of the feed water, (*b*) the temperature and pressure of the steam which is produced, (*c*) the character of the coal, (*d*) the temperature and composition of the air, and (*e*) the temperature and composition of the flue gases. In a certain sense this is true, but of course the fundamentally important thing is the knowledge that coal will burn and convert water into steam. Such fundamental knowledge is always taken for granted in the study of thermodynamics. The nature of fire is not an object of study in thermodynamics, but every one knows what fire is in a simple practical way; every one knows that an object becomes hot when it is placed upon a hot stove; and every one knows that steam will squirt out of a hole in a steam boiler under pressure. In the experience of the writer only one case has ever come to notice in which this kind of fundamental knowledge seemed to be lacking. A student was asked to define what is meant by the heat of combustion of coal, and he gave it correctly up to a certain point by saying that it was the number of thermal units generated by one pound of coal; it was, however, impossible to lead the young man by indirect suggestion to add the important qualifying phrase "when the coal is burned," and upon being asked explicitly how one gets heat out of coal, the young man actually replied, with some embarrassment, "Why, Professor, I don't know." Of course, he did know, but apparently he could only think that the study of thermodynamics must refer to unfamiliar and elegant things. No, thermodynamics refers to the things of the kitchen and to the things of the furnace, although the science of thermodynamics is so organized that it talks only of the things that go into and of the things which come out of those mysterious places where maids and furnace-men rule.

Limitations of Mechanics

The science of mechanics applies to the more or less ideal phenomena which are associated with the motion of rigid bodies either singly or in connected machines; with the regular motion of distortion of elastic bodies like the bending of a bow or the oscillation of a string; and with ideally simple motion of flow of liquids and gases like the smooth flow of water from an orifice in a tank. In every actual case of motion, however, we always encounter turbulence more or less marked, and the science of mechanics, which is the science of describing the phenomena of motion, fails utterly if we attempt to consider the

minute details of the phenomena of motion which are involved in this turbulence. Let one, for example, watch the movement of the water at a point in a brook. There is indeed a fairly steady average velocity of the water at the point and a certain mean rhythmic variation, but superposed upon this average motion there is an erratic variation of velocity which is infinitely manifold, the details of which are beyond the scope of any descriptive science. A descriptive science like mechanics is concerned with how things progress as a phenomenon develops itself; how the structural parts of a bridge stretch and shorten as a car passes across the bridge; how the pressure and temperature of steam vary during the successive stages of admission, expansion and exhaust of a steam engine; how electro-motive force, current strength, electro-magnetic force and all of the changing variables play in the operation of a dynamo. But who could recite the story of the most minute details of these phenomena? It can not be done, and if it could be done, it would be of no avail, for these details can never be twice alike and the very essence of a science lies in the discovery of types which in their important features recur so that a knowledge of these types may serve as a basis for anticipation and design.

Fire is the most familiar example of a turbulent phenomenon, and its most striking characteristic is that its progress is not dependent upon any external driving cause; when once started it goes forward of itself and with a rush. Tyndall in referring to this matter says that to account for the propagation of fire was one of the philosophical difficulties of the eighteenth century. A spark was found sufficient to initiate a conflagration, and the effect seemed beyond all proportion greater than the cause; herein lay the philosophical difficulty. Indeed the simple idea of cause and effect is not applicable to physical phenomena involving turbulence. Every physical phenomenon involving turbulence is to some extent self-sustaining, and every such phenomenon has a certain impetuous quality which may carry it beyond anything that is commensurate with the original initiating cause. These remarkable characteristics of turbulence are now definitely formulated as the second law of thermodynamics.

The most important practical thing in connection with the turbulent aspect of any physical phenomenon is its general result or consequence, just as the important thing about the burning of a house is the loss. How utterly useless and uninteresting it would be, for example, to study the minutest details of a conflagration (assuming such study to be possible), recording the height and breadth and the irregular and evanescent distribution of temperature throughout each flicker of consuming flame, the story of each crackling sound and the extent and character of every yield and sway of timber and wall! The fact is that we are immersed in an illimitable sea of phenomena, every single detail

of which is infinitely manifold, and no completely adequate science can ever be developed.

Physical science, then, aside from those branches which are dependent upon the atomic theory, consists of three branches, namely, (1) mechanics, including hydraulics, electricity and magnetism, light and sound; the science of those phenomena in which turbulence may for practical purposes be ignored; (2) statistical physics, the science of those phenomena in which turbulence introduces an appreciable and practically important erratic element. Such phenomena can be studied only by the statistical method, the record of individual cases and the study of averages. Meteorology is the best example of statistical physics, although every physical phenomenon has its statistical aspect; and (3) thermodynamics. Some of the features of thermodynamics have already been pointed out. It is the study of changes of state of substances. A most important aspect of thermodynamics remains, however, to be considered and the preliminary idea of this new aspect may be obtained by drawing a parallel. In every-day life we see the fire-insurance companies concerned with certain broad features of statistical physics in their examinations and records of fires, and we see them also concerned with a profit and loss account which is wholly abstracted from the details of the phenomena of conflagration. Thermodynamics is the profit and loss branch of physics as it were; and like the profit and loss branch of fire insurance, thermodynamics is completely abstracted from any consideration of the details of any physical phenomenon. Thermodynamics is concerned with the measurement and counting of that type of physical degeneration which accompanies turbulence just as fire insurance is concerned with the estimate and counting of what we might call, using a fine phrase, structural degeneration by fire.

Thermodynamic Degeneraton

Every one has a feeling of the irretrievable effects of disaster, the collapse of a bridge, the destruction of a house by fire, or the wreck of a ship; these things involve losses which indeed may be forgotten after reconstruction, but never balanced. The havoc wrought is essentially irreparable. It is desirable to use the word degeneration in a very narrow technical sense when we come to consider the second law of thermodynamics, and the way may be paved to a clear understanding of the later and accepted use of this word in physics by applying it now to designate that aspect of disaster which is irreparable. The burning of a building, for example, is a process of degeneration. It is very important, however, to avoid the carrying over of this idea of structural degeneration into thermodynamics, where a much more limited conception of degeneration arises. The term thermodynamic

degeneration applies to the effects of turbulence which always plays a certain havoc in a system. Thus a certain degeneration is associated with the turbulence which is produced when a hot iron is dipped into water, a certain degeneration is associated with the escape of a compressed gas through an orifice, a certain degeneration is associated with the flow of heat from a region of high temperature to a region of low temperature, a certain degeneration is associated with the conversion of work into heat by the rubbing of a coin on a board, and so on.

Reversible Processes

A substance in thermal equilibrium is generally under the influence of external agencies. Thus surrounding substances confine a given substance to a certain region of space, and they exert upon the given substance a definite constant pressure; surrounding substances are at the same temperature as the given substance and according to the atomic theory the molecules of the given substance rebound from the surrounding substance with their motion on the average unchanged; surrounding substances may exert constant magnetic or electric influences on the given substance; and so on. If the external influences which act upon a fluid in thermal equilibrium are made to change very slowly, causing the pressure, volume and temperature of the fluid to pass very slowly through a continuous series of values and in general involving the doing of work upon or by the fluid and the giving of heat to or taking of heat from the fluid, then the fluid will pass slowly through a process consisting of a continuous series of states of thermal equilibrium. Such a process is called a reversible process, for the reason that the fluid will pass through the same series of states in reverse order if the external influences are changed slowly in reverse sense.

Irreversible Processes

When a substance is settling or tending to settle to thermal equilibrium it may be said to undergo a process. Such a process can not be arrested or held at any stage short of complete thermal equilibrium, but it always and inevitably proceeds towards that state. Such a process may, therefore, be called a sweeping process or simply a sweep. The settling of a closed system to thermal equilibrium may be called a simple sweep. For example, the equilibrium of a mixture of oxygen and hydrogen in a closed vessel may be disturbed by a minute spark, and the explosion of the gases together with the subsequent settling of the water vapor to a quiescent state constitutes a simple sweep. The equilibrium of a gas confined under high pressure in one half of a two-chambered vessel may be disturbed by opening a cock which connects the two chambers, and the rush of gas into the empty chamber

constitutes a simple sweep. When external influences change continuously a substance in its tendency to settle to thermal equilibrium never catches up with the changing conditions, but trails along behind them, and we have what may be called a trailing sweep. Thus the rapid heating or cooling of a gas in a vessel is a trailing sweep. So long as heat is given to or taken from the gas at a perceptible rate there will be perceptible differences of temperature in different parts of the gas; and the gas in its tendency to settle to thermal equilibrium never catches up with the increasing or decreasing temperature of the walls of the containing vessel.

Steady Sweeps

A substance may be subjected to external action which, although permanent or unvarying, is incompatible with thermal equilibrium. When such is the case the substance settles to a permanent or unvarying state which is not a state of thermal equilibrium. Such a state of a substance may be called a steady sweep. For example, the two faces of a slab or the two ends of a wire may be kept permanently at different temperatures, and when this is done the slab or wire settles to an unvarying state which is by no means a state of thermal equilibrium. Heat flows through the slab or along the wire from the region of high temperature to the region of low temperature. This flow of heat through the slab or along the wire is an irreversible process and it constitutes a steady sweep. The ends of a wire may be connected to a battery or dynamo so that a constant electric current flows through the wire and the heat which is generated in the wire by the current may be steadily carried away by a stream of water or air. Under these conditions the wire settles to an unvarying state which is by no means a state of thermal equilibrium, the battery or dynamo does work on the wire and this work reappears steadily as heat in the wire.

Thermodynamic Degeneration

Every one must admit that the impetuous character of a sweeping process suggests a certain havoc, a certain degeneration in the substance or system in which the sweep takes place. Consider, for example, a charge of gun-powder which has been exploded; if it is exploded in a large empty vessel, everything is there after the explosion, all of the energy is there and all of the material substance is there, but it can not be exploded a second time! The man on the street has heard much during recent years of the conservation of energy and of the conservation of matter, and the old proverb that "you can't eat your cake and have it" presents to his mind a question which in its less familiar forms, as relating to engines for example, he tries in vain to rationalize in terms of these principles of conservation. Nearly all of the intuitive

sense of the man on the street concerning these matters (and he has a great deal) is involved in the second law of thermodynamics, which is not a law of conservation at all. It is a law of waste.

At this point of our discussion it is necessary to use the word degeneration so as to express more or less tentatively the idea that every sweeping process brings about a definite amount of degeneration, an amount that can be expressed numerically just as one speaks of so many pounds of sugar or so many yards of cloth. Thus a certain amount of degeneration is brought about when a compressed gas escapes through an orifice, a certain amount of degeneration is brought about when heat flows from a region of high temperature to a region of low temperature, a certain amount of degeneration is brought about when work is converted into heat by friction or by the flow of an electric current through a wire, and so on.

In a simple sweep the degeneration lies wholly in the relation between the initial and final states of the substance. This is necessarily the case because no outside substance is affected in any way by the sweep, no work is done on or by the substance which undergoes the sweep and no heat is given to or taken from it. In a trailing sweep the degeneration may lie partly in the relation between the initial and final states of the substance which undergoes the sweep, partly in the conversion of work into heat, and partly in the flow of heat from a high temperature region to a low temperature region. In a steady sweep, however, the substance which undergoes the sweep remains entirely unchanged as the sweep progresses, and the degeneration lies wholly in the conversion of work into heat, in the transfer of heat from a region of high temperature to a region of low temperature, or in both. Therefore the idea of thermodynamic degeneration as a measurable quantity can be reached in the simplest possible manner by a careful scrutiny of a steady sweep.

Proposition (*a*).—The thermodynamic degeneration which is represented by the direct conversion of work into heat at a given temperature is proportional to the quantity of work so converted. Consider, for example, a steady flow of electric current through a wire from which the heat is abstracted so that the temperature remains constant. This process is steady, that is to say, it remains unchanged during successive intervals of time, and therefore any result of the process must be proportional to the time which elapses, that is to say, the amount of degeneration occurring in a given interval of time is proportional to the time, but the amount of work which is degenerated into heat is also proportional to the time. Therefore the amount of degeneration is proportional to the amount of work converted into heat at the given temperature.

Proposition (*b*).—The thermodynamic degeneration which is rep-

resented by the transfer of heat from a given high temperature T_1 to a given low temperature T_2 is proportional to the quantity of heat transferred. Consider a steady flow of heat from temperature T_1 to temperature T_2 constituting a steady sweep, a sweep which remains entirely unchanged in character in successive intervals of time. Any result of this sweep must be proportional to the lapse of time, and therefore the degeneration which takes place in a given interval of time is proportional to the time; but the quantity of heat transferred is also proportional to the time, therefore, the amount of degeneration is proportional to the quantity of heat transferred from temperature T_1 to temperature T_2.

Kelvin's Definition of Temperature Ratio

The definition of the ratio of two temperatures previously given was understood to be a provisional definition. We are now in a position to propose a definition of the ratio of two temperatures which is independent of the physical properties of any particular substance. This definition will remain somewhat vague, however, until the action of the steam engine is discussed in the later sections of this article. According to proposition (*a*) above, the thermodynamic degeneration which is involved in the conversion of work into heat at a given temperature is proportional to the amount of work so converted and the proportionality factor depends upon the temperature only. Therefore, we may write

$$\phi' = m_1 W \tag{2}$$

and

$$\phi'' = m_2 W \tag{3}$$

where ϕ' is the degeneration involved in the conversion of an amount of work W into heat at temperature T_1, and ϕ'' is the degeneration involved in the conversion of an amount of work W into heat at temperature T_2, and m_1 and m_2 are factors which depend only upon T_1 and T_2, respectively. The amount of work W having been converted into heat at temperature T_1, imagine the heat to flow to a lower temperature T_2, thus involving an additional amount of degeneration according to proposition (*b*) above. The conversion of work W into heat at temperature T_1 and the subsequent flow of this heat to a lower temperature T_2 gives the same result as would be produced by the conversion of the work into heat at the lower temperature directly. Therefore the lower the temperature at which work is converted into heat the greater the amount of degeneration involved. That is to say, the factor m_2 in equation (3) is larger in value than the factor m_1

in equation (2), temperature T_1 being higher[6] than temperature T_2. Therefore, since m_1 and m_2 depend only upon T_1 and T_2, respectively, it is permissible to adopt the equation

$$T_1/T_2 = m_2/m_1 \tag{4}$$

as the definition of the ratio T_1/T_2. This definition of temperature ratios is originally due to Lord Kelvin.

Another way to express the definition which is involved in equation (4) is to consider that the factor m_1 is the smaller the higher the temperature T_1, so that we may adopt k/m_1 as the measure of the temperature T_1 and k/m_2 as the measure of the temperature T_2, giving

$$m_1 = k/T_1 \tag{5}$$

and

$$m_2 = k/T_2 \tag{6}$$

where k is an indeterminate constant. Therefore equations (2) and (3) may be written in the general form

$$\phi = kW/T \tag{7}$$

where ϕ is the thermodynamic degeneration involved in the conversion of an amount of work W into heat at temperature T, and k is an indeterminate constant.

The ratio of two temperatures as defined by equation (4) is very nearly the same as the ratio of two temperatures as measured by the gas thermometer, and therefore gas thermometer temperatures may be used throughout this discussion without appreciable error.[7]

Since the factor k in equation (7) is indeterminate, we may use as our unit of thermodynamic degeneration the amount which is involved in the conversion of one unit of work into heat at a temperature of one degree on the "absolute" scale; then the value of k is unity and equation (7) becomes

$$\phi = W/T \tag{8}$$

[6] The idea of higher and lower temperature is not dependent upon any method of measuring temperature. When a substance receives heat definite observable effects are produced, and when these effects are produced by placing one substance in contact with another substance, the other substance is known to give heat to the given substance and its temperature is known to be higher than the temperature of the given substance. Does not one know that a stove is hotter than the floor, for example, when one spills water partly on the stove and partly on the floor?

[7] One of the most important discussions in elementary thermodynamics is that which establishes this fact. See Art. 58 of Franklin and MacNutt's "Elementary Theory of Heat" for a very simple discussion of this matter.

in which W is expressed in joules and T in degrees centigrade; and ϕ is expressed in terms of joules per degree. Thus one joule per degree is the degeneration involved in the conversion of one joule of work into heat at 1° C. on the absolute scale, or the amount involved in the conversion of 1,000 joules into heat at 1,000° C. on the absolute scale.

To convert an amount of work W into heat at temperature T_1 involves W/T_1 units of degeneration, to convert the same amount of work into heat at temperature T_2 involves W/T_2 units of degeneration, and therefore to transfer an amount of heat equal to W from temperature T_1 to temperature T_2 must involve an amount of degeneration equal to the excess of W/T_2 over W/T_1 or an amount equal to $W(1/T_2 - 1/T_1)$, or $H(1/T_2 - 1/T_1)$, where H is the amount of heat transferred.

The Second Law of Thermodynamics

(*a*) The thermodynamic degeneration which accompanies a sweeping or irreversible process can not be directly repaired, nor can it be repaired by any means without compensation.

This is an entirely general statement of the second law of thermodynamics. The *direct repair* of the degeneration due to the sweeping process means the undoing of the havoc wrought by the process by allowing the sweep to perform itself backwards, an idea which is exactly as absurd as the idea of allowing a burned house to unburn itself. Following are several specialized statements of the second law of thermodynamics.

(*b*) Heat can not pass directly from a cold body to a hot body, nor can heat be transferred from a cold body to a hot body by any means without compensation.

(*c*) Heat can not be converted directly into work, nor can heat be converted into work by any means without compensation.

The direct conversion of heat into work would be the simple reverse of any of the ordinary sweeping processes which involve the degeneration of work into heat, that is, the direct conversion of work into heat would be to allow the sweeping process to perform itself backwards. For example, work is degenerated into heat in the bearing of a rotating shaft, and we all know that to reverse the motion of the shaft does not cause the bearing to grow cold and the heat so lost to appear as work helping to drive the shaft. That would be a rotary engine indeed! There is an important general theorem in thermodynamics to the effect that if two sweeping processes A and B involve the same amount of degeneration, and if either of the processes, say A, has been allowed to perform its sweep, then by a lever arrangement, as it were, the process

B can be carefully *let down*, and the havoc wrought by the sweep of *A* can be undone. The result of this operation, however, would be to leave the system *B* in the condition in which it would be degenerated if the process *B* had been allowed to sweep instead of being *let down*. This is very much as if, having two similar houses *A* and *B*, one of which *A* has been burned, we could rig up a mechanism which would *let down B* to ashes and cause *A* to be restored in the original actual materials of which it was first constructed. This is of course impossible in the case of the two houses, but it is possible in every known case of thermodynamic degeneration. This general theorem is as thoroughly established as any generalization in physics, and if it is true and if we ever find a way to convert heat into work unconditionally and without cost or compensation, then it will be proved indirectly that a shaft *can* be driven by heating one of the bearings in which it rotates, for direct conversion of work into heat by one process must be according to this general theorem equivalent to and replaceable by the reverse of any ordinary sweeping process which converts work into heat.

(*d*) A gas cannot pass directly from a region of low pressure into a region of high pressure, nor can a gas be transferred from a region of low pressure to a region of high pressure by any means without compensation.

Imagine a gas squirting itself backwards through a nozzle into a high-pressure reservoir! The repeated statement of self-evident facts concerning direct repair in these statements of the second law of thermodynamics may seem ridiculous to the intelligent reader, but the second law of thermodynamics is a statement of a fact which every one knows coupled with a generalizing clause which, once thoroughly understood, is almost if not quite self-evident.

Here is one more statement of the second law of thermodynamics, the oldest English version of it:

> **Humpty Dumpty sat on a wall,**
> **Humpty Dumpty had a great fall,**
> **All the king's horses and all the king's men**
> **Can not put Humpty Dumpty together again.**

This is perhaps the most sensible of all the statements of the second law, for which we will allow it to pass for the moment, inasmuch as it ignores direct repair and refers at once to the most powerful of external means. It is important, however, to remember that in Humpty Dumpty's case we are concerned with structural degeneration, not with the much simpler kind of degeneration in a structureless fluid due to turbulence.

Of all the generalizations of physics, the second law of thermodynamics is certainly the most deeply seated in the common sense of

men, and one of the most humorous of children's verses refers to the man whose wondrous wisdom enabled him to circumvent it by direct repair:

There was a man in our town,
And he was wondrous wise;
He jumped into a bramble bush
And scratched out both his eyes.
And when he found his eyes were out,
With all his might and main,
He jumped into another bush
And scratched them in again.

Let us return to the fourth statement (*d*) and consider with the help of an example what is meant by compensation in its thermodynamic sense. A gas *can* be transferred from a region of low pressure to a region of high pressure by means of a pump, and the work that is done in driving the pump, even supposing the pump to be frictionless, is all converted into heat. This conversion of work into heat is the necessary cost or compensation for the transfer of the gas from the low pressure region to a high pressure region.

Consider the second statement (*b*). In an artificial ice factory heat *is* continually abstracted from the freezing-room and transferred to the warm outside air; but to accomplish this result, even by an ideally perfect frictionless mechanism, a certain amount of work is required to drive the ammonia pump and this work is converted into heat. This conversion of work into heat compensates for the transfer of heat from the freezing-room to the warm region outside.

Consider the third statement (*c*). In ordinary steam engines, heat *is* converted into work, but to accomplish this transformation a large quantity of heat must be supplied to the engine at high temperature, and some of this heat (about nine tenths of it in the very best of steam engines) must be let down, as it were, to the low temperature of the exhaust to compensate for the conversion of the remainder into work.

Heat Engines

An engine, or to be more specific, a heat engine is a machine for converting heat into mechanical work. The engine is supplied with heat at a high temperature, it transforms a portion of this heat into work, and it delivers the remainder of the heat to a low temperature region. Figure 1 is a diagram for fixing in the reader's mind the various temperatures and quantities of heat and work which are involved in the operation of an engine. The boiler is at high temperature T_1, and the condenser is at low temperature T_2. When the engine is operated for a time, a quantity of heat H_1 is taken from the boiler, an amount of heat W is developed by the engine (in excess of the work

required to drive the feed water pump), and the quantity of heat H_2 is delivered to the condenser.

According to the first law of thermodynamics, the work W must be equal to $H_1 - H_2$, both quantities of heat being expressed in energy units. Therefore

$$W = H_1 - H_2 \tag{9}$$

As far as the net result is concerned the operation of the steam engine may be thought of as (a) the conversion into work of the whole of the heat H_1 from temperature T_1, and (b) the reconversion of a

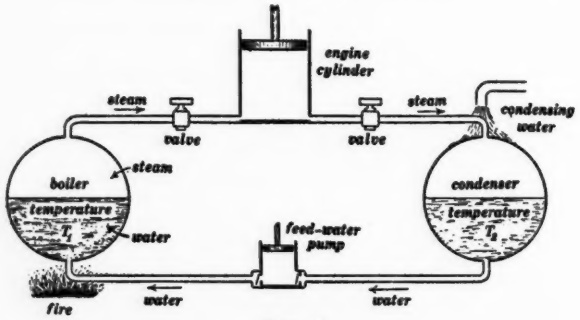

FIG. 1.

portion H_2 of this work into heat at temperature T_2. The regeneration[8] associated with process (a) is equal to H_1/T_1 according to equation (8), and the degeneration associated with process (b) is equal to H_2/T_2 according to equation (8). If the operation of the engine involves sweeping processes, then the degeneration H_2/T_2 must exceed the regeneration H_1/T_1, that is, we must have

$$H_2/T_2 > H_1/T_1 \tag{10}$$

or, substituting the value of H_2 from equation (9) and solving for W, we have

$$W < \frac{T_1 - T_2}{T_1} H_1 \tag{11}$$

The fractional part $[(T_1 - T_2)/T_1]$ of the heat H_1 which is converted into work by the engine is called the efficiency of the engine, and the inequality (11) shows that the efficiency of any engine working between temperatures T_1 and T_2 must be less than $[(T_1 - T_2)/T_1]$ whatever the nature of the working fluid and whatever the design of the engine.

The Perfect Engine.—An engine involving no irreversible or sweep-

[8] To convert an amount of work W into heat at a given temperature involves an amount of degeneration, and to convert the heat into work involves the same amount of what may be called thermodynamic regeneration.

ing processes in its operation would be called a perfect engine. In such an engine the degeneration H_2/T_2 above mentioned would be equal to the regeneration H_1/T_1 so that for a perfect engine we should have

$$H_2/T_2 = H_1/T_1 \tag{12}$$

or

$$T_1/T_2 = H_1/H_2 \tag{13}$$

Substituting the value of H_2 from equation (9) in equation (12) or (13), and solving for W, we have

$$W = \frac{T_1 - T_2}{T_1} H_1 \tag{14}$$

This equation shows that the efficiency of any perfect engine working between the temperatures T_1 and T_2 would be equal to $[(T_1 - T_2)/T_1]$.

Lord Kelvin's definition of the ratio of two temperatures may be understood with the help of equation (13) in which H_1 and H_2 are the amounts of heat taken in and given out by a perfect engine during a given time, and T_1 and T_2 are the temperatures between which the engine is working.

Efficiencies of Engines in Practise.—A fraction of the heat which is delivered to an engine with the steam which drives the engine is converted into work. In order that this fraction may be large, the ratio T_1/T_2 must be as large as possible, and sweeping processes must be obviated as much as possible in the operation of the engine; T_1 being the temperature of the steam supplied to the engine, and T_2 being the temperature of the exhaust. The ratio of the initial temperature to the final temperature of the expansion steam or gas in an engine depends upon the ratio of the initial volume to the final volume of the steam or gas.

In order that moderately small cylinders[9] may be used for the development of a given amount of power, the initial pressure of the steam or gas must be high; and in order that the final temperature may not be lower than atmospheric or available condenser water temperatures, the initial temperature must be high. The first point concerning high initial pressures is exemplified in the operation of the ordinary gas or gasoline engine in which the mixed charge of gas and air is highly compressed before it is exploded.

In the gas engine the initial temperature is the temperature of the

[9] The objections to large cylinders are: (*a*) their great cost, (*b*) the great amount of heat radiated by them, (*c*) the great amount of cylinder condensation in a large cylinder as explained later, and (*d*) the great amount of piston friction and cost of lubrication.

mixture of air and gas immediately after the explosion and it may be from 1,200° to 1,700° C. on the absolute scale; and the temperature is reduced by expansion to perhaps half this value. The temperature and pressure of the steam which is supplied to a steam engine is seldom higher than 190° C. (463° on the absolute scale) and about 175 pounds per square inch, respectively. Any higher temperature and pressure involves a great deal of danger in the boiler. The lowest condenser temperature in steam engine practise is about 50° C. (323° on the absolute scale).

The sweeping processes which take place in a steam engine are as follows:

(*a*) Friction between the moving parts of the engine. This friction results in the immediate reconversion into heat of a portion of the mechanical energy developed by the engine.

(*b*) Wire drawing. If the pipes and passages traversed by the steam through the boiler to the engine are small, the pressure in the cylinder with open ports will be lower than boiler pressure, so that the entering steam passes from a region of high pressure into a region of low pressure. Also as the cut-off valve closes, steam will rush into the cylinder through a narrowing aperture. This effect is called wire drawing, and to provide against loss of efficiency from this cause the pipes must be of ample size and the cut-off valve must operate very quickly.

(*c*) Radiation. The cooling of pipes and cylinders by the giving of heat to surrounding cooler bodies is a sweeping process, and is to be obviated as much as possible by covering the pipes and the cylinder with a thick coating of porous insulating material.

(*d*) Cylinder condensation. As a charge of steam in the cylinder expands it cools and cools the cylinder and piston, so that when steam is next admitted it heats cylinder and piston up again and is itself cooled. This effect can not be eliminated, but it can be largely reduced by providing separate passages for the ingress and egress of steam; and by using a series of cylinders of increasing size of which the smallest cylinder takes steam directly from the boiler and exhausts into the next large cylinder, which in turn exhausts into a still larger cylinder, and so on. In this way the range of temperature in each cylinder is small and the effects of cylinder condensation are greatly reduced. A steam engine in which expansion of the steam takes place in two stages (in two cylinders) is called a compound engine. An engine in which the expansion of the steam takes place in three stages (in three cylinders) is called a triple expansion engine.

The loss of efficiency due to cylinder condensation is greatly reduced by the use of superheated steam because the exchange of heat between the steam and the cylinder walls is very greatly reduced when the steam

does not condense. Thus, S. LeRoy Brown has found that heat is imparted to a metal surface about twenty-four times as fast by condensing steam than by a gas at the same temperature.

(*e*) Effect of high piston velocity. If the piston speed is too great, the pressure of the expanding steam becomes ineffective because the portions of the steam near the moving piston are expanded and cooled before the remote parts of the steam are affected. This effect is negligible at the highest piston velocities which are mechanically feasible.

(*f*) Puffing. When the steam at the end of a stroke is still at a pressure which exceeds the pressure in the condenser (or which exceeds the pressure of the outside air when no condenser is used), it rushes through the exhaust port as a sharp puff. Puffing is to be avoided by sufficiently reducing the steam pressure by expansion in the cylinder.

The greatest items of waste in the ordinary sense of actual loss of heat are (*a*) the incomplete combustion of the fuel and (*b*) the carrying away of great quantities of heat in the flue gases. The economic use of fuel for the production of mechanical power requires, therefore, a properly designed furnace and intelligent and careful stoking to insure complete combustion, and it requires a sufficient exposure of boiler surface and frequent cleaning of the same to facilitate the flow of heat from the hot gases into the boiler.

The most pronounced sweeping process which intervenes between the completed combustion and the final exhaust of the steam is the flow of heat from the very high temperature of the fire in the furnace to the moderately low temperature of the water in the boiler, and the greatest waste in the operation of the steam engine in the sense of loss of availability of heat for conversion into work is involved in this sweeping process, and it can hardly be avoided in the steam engine because of the danger involved in the generation of steam at very high pressure in a large boiler.

The best gas engines convert about 30 per cent. of the heat of the fuel into mechanical work. The best steam engines convert about 10 or 12 per cent. of the heat of the fuel into mechanical work. The ordinary run of steam engines convert only 4 or 5 per cent. of the heat of the fuel into mechanical work.

(*This article is to be followed by a second article on entropy.*)

CLIMATE IN SOME OF ITS RELATIONS TO MAN[1]

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Climatology and Meteorology.—In a course of lectures dealing with the present status of meteorology the subject of climate, upon which I have the honor to address you this afternoon, finds an appropriate place. For meteorology and climatology are interdependent, and it is impossible to distinguish very sharply between them. In a strict sense, meteorology deals with the physics of the atmosphere, and those of you who have attended the preceding lectures in this course have listened to able discussions of the physical problems with which meteorologists are to-day concerned. The view taken by meteorology is largely theoretical, but the main object in the solution of most of these problems is to make this science of immediate practical service to man, in improving and extending our weather-forecasts.

When the term meteorology is employed in its broadest sense, climatology is a subdivision of meteorology. Climatology is largely descriptive. It rests upon physics and geography, the latter being a very prominent factor. In fact, climatology may almost be defined as geographical meteorology. The main object of climatology is also to be of practical service to man. Its method of treatment lays the most emphasis upon the elements which are of the most importance to life. Climate and health, climate and industries, climate and crops, climate and transportation—these are subjects of vital human interest. It is my privilege this afternoon to suggest a few of the points of contact between man and his climate. If my discussion seems disjointed and haphazard, I beg of you to remember that the subject is one of the widest possible range; it concerns all men, in all parts of the world. To select from this immense body of facts the few which it is possible to touch upon in an hour is like trying to decide which of a thousand snowflakes is the most symmetrical; or to determine, in a wonderful view across the snow-covered mountains on a brilliant winter's day, whether it is the sun, or the crisp air, or the snow, or the contour of the hills, or the grouping of the trees, or the picturesque farmhouses, which really contribute most to make the picture what it is.

The Climatic Zones.—So great is the variety of climates to be found in the world that it has long been customary to classify these climates into certain broad belts, which we call the zones. These were first suggested, on purely astronomical grounds, in the times of the early Greek philosophers and geographers. It is to be noted

[1] Lecture delivered at Columbia University, March 2, 1909.

that these zones are really zones of sunshine, or of solar climate, a subject which Professor Libbey has already considered in his lecture on "Astronomical Climate" (January 19, 1909). The so-called "torrid" zone has the greatest annual amount of sunshine. It is the summer zone. The polar zones have the smallest amount of sunshine. They may well be called the winter zones. The temperate zones are intermediate between the tropical and the polar, in the matter of the annual amount and of the annual variation of sunshine.

The Temperature Zones.—The usual classification of the climatic zones on the basis of the distribution of sunshine serves well enough for purposes of simple description, but a glance at any temperature-chart shows at once that the lines of equal temperature (isotherms) do not coincide with the lines of latitude. In fact, in the higher latitudes, the lines of equal temperature often follow the meridians more closely than they do the parallels of latitude. The astronomical zones—*i. e.*, the zones of light—therefore differ a good deal from the zones of heat. Hence, in recent years, it has become quite customary, at least in climatology, to limit the zones by lines of equal temperature, thus making a closer approach to the actual conditions of climate.

Characteristics of the Tropics.—The dominant characteristic of the great equatorial zone is the remarkable simplicity and uniformity of its climatic features. The tropics lack the proverbial uncertainty and changeableness which characterize the weather of the higher latitudes. Within the tropics, weather and climate are essentially synonymous terms. Regular conditions, which depend upon the daily and annual march of the sun, are dominant. Irregular weather changes are wholly subordinate. In special regions only, and at special seasons, is the regular sequence of weather temporarily interrupted by an occasional tropical cyclone. These cyclones—the hurricanes of the West Indies and the typhoons of the China seas belong to the group—although infrequent, are notable features of the climate of the areas in which they occur. The devastation produced by one such storm often affects the economic condition of the people in the district of its occurrence for years.

Over nearly all the equatorial zone the difference between the average temperatures of the warmest and coldest months is less than 10°, and over much of it it is less than 5°. At Equatorville, in the interior of Africa, on the Congo, the difference between the average temperature of the warmest and coolest months is only a little over 2°. The variation in temperature during the day is usually larger than this seasonal difference. Thus, at Equatorville it is seven times as large. It has been well said that "night is the winter of the tropics." Over much of the equatorial zone the lowest temperatures usually do not fall below 60°. Maximum temperatures of 115°–120° occur over the deserts of northern Africa.

In a true tropical climate seasons, in our sense, do not exist. The variations in temperature throughout the year are so slight that the seasons are not classified according to temperature, but depend on rainfall and the prevailing winds. The life of animals and of plants in the tropics, and of man himself, is regulated very largely, in some cases almost entirely, by rainfall. Although the tropical rainy season is characteristically associated with a vertical sun (*i. e.*, "summer"), that season is not necessarily the hottest time in the year. In fact, the temperature is usually somewhat lower under the clouds, and hence the rainy season often goes by the name of "winter."

Within the tropics the equatorial belt of calms and variable winds —the "doldrums" of sailors—offers exceptionally favorable conditions for abundant rainfall. The rainfall is so heavy that the surface waters of the ocean are actually fresher than in the latitudes to the north and south. The sky is prevailingly cloudy; the air, hot and oppressive; heavy showers and thunderstorms are frequent. In the latitudes of this belt are the dense tropical forests of the Amazon and of equatorial Africa. Here drought and frost need not be feared. The belt of calms and rains shifts north and south of the equator after the sun. It is dreaded by seamen because sailing vessels are apt to be delayed in crossing it, but delays of great length are infrequent nowadays, since a careful study of the prevailing winds over the ocean areas has shown navigators at what points the belt of calms is narrowest, and where the crossing may be the most successfully made.

In striking contrast are the easterly trade winds, which blow toward the equator from about latitude 30° north and south. Of great regularity, embracing about one half of the earth's surface, the trades have long been favorite sailing routes because of the steadiness of their winds, the infrequency of their storms, the brightness of their skies and the freshness of the air, all of which are in pleasing contrast with the muggy, oppressive calms of the doldrums. All sailing routes which pass through the trade wind belts in any ocean are controlled by these winds. Steady winds like the trades certainly tempted the early navigators to put to sea. The famous voyage of Columbus was facilitated, if not made possible, by the northeast trade. The easy outward voyages of the early Spanish adventurers and colonists took them naturally to that portion of the Americas where they found even-tempered climates in which they and their descendants could live comfortably. The monsoons of India have from the earliest days of trade with the east been important agents in aiding commerce.

The most desirable house sites in the tropics are very commonly on the top of some elevation, exposed to the trades. The sea breeze, also, is an important climatic feature on many tropical coasts. With its regular occurrence, and its cool, clean air, it serves to make many districts habitable for white settlers, and has deservedly won the name of

"the doctor." The location of dwellings is often determined by the exposure of a site to this wind. For this reason, many native villages are placed as near the sea as possible. The houses of well-to-do foreigners often occupy the healthiest and most desirable locations, where the sea breeze has a free entrance, while the poorer native classes live in lower, less exposed, and less desirable places. A social stratification is thus determined by the sea breeze. In our own latitudes, exposure to sunshine is very important, as is well known, in determining house sites. Lugeon's study of one of the principal valleys between Martigny and the Rhone Glacier, has brought out some interesting facts in this connection. In this district the villages, with one or two exceptions, are on the sunny side. In fact, a distinction of classes results from this difference. There is developed what may be called an "aristocracy of the sun." The people on the sunny side are more prosperous and better educated, and look with some contempt upon the people on the shady side.

The trades, except where they blow onto windward coasts, or over mountains, are dry winds. On the lowlands swept over by the trades, beyond the polar limits of the equatorial rain belt (roughly between latitudes 20° and 30°) are most of the great deserts of the world. The interior of Africa has been out of contact with the civilized world largely because of the deserts to the north and south of it. Goods and passengers go around rather than across these deserts. In the desert, population gathers in oases, as on islands. Here the trails followed by the caravans converge like sailing routes at sea. There are small Arabian towns, built at oases, where the houses are almost crowded on top of one another, producing something not unlike the modern "sky scraper" of an American city, where land is scarce and expensive.

The overflow of the Nile results from the rainfall on the mountains of Abyssinia during the northward migration of the belt of equatorial rains; and one of the most difficult problems in the construction of the Panama Canal, viz., the control of the floods of the Chagres River, is due to a similar cause.

The monsoons, reference to which was made a moment ago, are a special development of the general trade wind system. Monsoon regions have summer rainfall, and these rains are particularly heavy where the winds have to climb over high land. Thus, in India, the precipitation is heaviest at the head of the Bay of Bengal, where in the Khasi Hills, at a height of a little less than a mile above sea level, the rainfall averages between 35 and 40 feet a year. This is about ten to twelve times as much as the rainfall of New York City, and all this water falls in less than six months. Truly, at that place, "it never rains but it pours." In certain parts of India stores of provisions are laid in before the rains begin, the preparations being similar to those made on board a vessel bound on a long voyage. Special mention may

be made here of a peculiar relation between climate and man in the case of certain tropical mountains which are high enough to receive snow instead of rain on their upper slopes. These mountains furnish a supply of snow and ice for refrigerating purposes in the towns below them. Thus, in Ecuador, snow is carried to Quito from the upper slopes of Pichincha; to Riobamba and Ambato from the slopes of Chimborazo. Guayaquil was formerly supplied with ice in the same way. In Colombia, Popayan, in the department of Cauca, is also supplied with ice and snow from the neighboring mountains. In Mexico, snow is carried from the summit of Colima to the towns on the hot plains below. The occupation of the Indians who bring down this ice from their tropical mountain tops is a curious example of climatic control.

Characteristics of the Temperate Zones.—The so-called "temperate zones" occupy about one half of the earth's surface. The north temperate zone includes the greatest known extremes of temperature, and if the word "temperate" were not so firmly established it would be well to change the name to "intermediate." A marked changeableness of the weather is a striking characteristic of these zones. For most of the year, and most of the temperate zones, settled weather is unknown. Climate and weather are here by no means synonymous. The changeableness of the weather suggests our never-failing subject of conversation. In the tropics no one talks about the weather, for it is monotonously the same, day after day.

In the north temperate zone the differences in temperature between the warmest and coldest months reach 120° at their maximum, in northeastern Siberia. An average January temperature of — 60° and an average July temperature of 95°, with maxima of over 120° and minima lower than — 90°, occur in this same zone.

The prevailing winds of the "temperate zones" are the westerlies, which occupy about as much of the earth's surface as do the easterly trades. The westerlies are, however, less regular than the trades, being much confused and interrupted by storms. So common are such interruptions that the prevailing westerly wind direction is often difficult to discern without careful observation. The south temperate zone is chiefly water. Hence the westerly winds are there but little interfered with by land. "Roaring forties" is a well-known designation for the southern middle latitudes, and between latitudes 40° and 60° south the well-named "brave west winds" blow with a constancy and a velocity hardly known in the northern hemisphere. Storms, frequent and severe, characterize these southern hemisphere westerlies. Voyages to the west around Cape Horn against head gales, and in cold, wet weather, are much dreaded, and are apt to be long and dangerous.

Between the trades of the tropics and the westerlies of the temper-

ate zones lies a debatable belt, shifting seasonally. Within it, stormy westerlies and drying trades alternately hold sway. It is known as the "subtropical belt." With prevailingly fair skies, even temperature and moderate rainfall, the subtropical belt is a favored climatic region, where invalids seek health, and an escape from the rigors of a cold winter is found by many who have the time, and the means, to leave their northern homes. The long list of well-known health resorts on the Mediterranean, and the shorter list for southern California—"the American Riviera"—bear witness to the popularity of this subtropical belt.

Seasons in most of the temperate zones are classified according to temperature—not, as in the tropics, by rainfall. The four seasons are important characteristics, especially of the middle latitudes of the north temperate zone. These seasonal changes are of the greatest importance in the life of man. They control his occupations, his crops, his place of residence, to a considerable extent his health.

The north temperate zone embraces so great a variety of climates that no single district can be taken as typical of the whole. Its climate has been called "a crazy quilt of patches." The south temperate zone, on the other hand, may be described as a piece of fairly uniform texture and appearance throughout. This is the effect of the large ocean surface. The whole climatic régime is more uniform than that of the northern zone. The south temperate zone may truly be called "temperate," but our own zone is certainly in the highest degree "intemperate."

Characteristics of the Polar Zones.—The climate of the polar zones gains a peculiar character by reason of the longer or shorter absence of the sun. At the poles themselves, the day and the year are alike. In the Arctic climate, plants must make rapid growth in the short, cool summer. They grow and blossom with great rapidity and luxuriance where the exposure is favorable, and where the water from the melting snow can run off. Over great stretches of the northern plains the surface only is thawed out in the warmer months, and swamps, mosses and lichens are found above eternally frozen ground. In high latitudes, where the exposure is good, snow melts in the sun even when the temperature of the air in the shade is far below freezing. It has been reported that at Assistance Bay, latitude 74.5° north, in March, when the air temperature was about —25°, snow near stones and other dark objects melted in the sun. The temperature in the immediate vicinity of the North Pole is probably a little below —40° in January; below 32° in July and a few degrees below 0° for the average of the year. It may be noted, however, that northeastern Siberia has a January mean temperature which is 20° lower than that at the North Pole in the same month.

For the Antarctic our knowledge is still very fragmentary. The

low temperatures of the south polar summer, which are probably due to the great continental mass of ice around the south pole, are responsible for much of the difficulty of Antarctic exploration. The average annual temperatures have been in the vicinity of 10°–15°; and the minima of an ordinary Antarctic winter go down to —40°, and below, but so far no minima of the severest Siberian intensity have been noted. The British expedition on the *Discovery* recorded a minimum temperature of —67.7°, and also noted —40° in midsummer. The highest temperatures have varied between about 35° and 50°. It is likely that near the south pole will prove to be the coldest point on the earth's surface in the average for the year, and also that the lowest winter and summer temperatures in the southern hemisphere will be found in the immediate vicinity of the pole.

The polar zones have a permanent deficiency of precipitation (15–10 inches, or less). The polar deserts of snow and ice are therefore deserts in more senses than one, although it is natural that these extended snow and ice fields should tend to give an exaggerated idea of the actual amount of snowfall. So far as exploration has yet gone into the highest northern latitudes, rain has been found to fall in summer, and it is doubtful whether there are any places in the world, near sea-level where *all* the precipitation comes in the form of snow. Perhaps the interior of the south polar continent may never have rain. The snow of the polar regions is characteristically fine and dry, and it has been pointed out that the snow huts of the Eskimos could not be built with our kind of snow. At low polar temperatures *flakes* of snow are not found, but precipitation is in the form of ice spicules.

The inner polar areas seem to be beyond the reach of the most frequent and most violent storms, and as most of the observations thus far obtained from the Antarctic come from the marginal zone of great storm activity, violent winds and wet, disagreeable weather, they do not show us the features of the actual south *polar* climate. Extraordinary records of storm and gale have been brought back from the far south and the far north. During the long, dreary winter night the temperature falls to very low readings. Snowstorms and gales alternate at irregular intervals with calmer spells of more extreme cold and clear skies. There is no really warm season. The summer is essentially only a modified winter, especially in the Antarctic. Yet the Arctic summer, with its long days, crisp, clean air and sunshine, has many attractive qualities, and we may fairly safely predict a considerable development of summer resorts within the Arctic circle for the pleasure-loving, wealthy and unoccupied persons of the north temperate zone.

Climate and Health.—We have now seen something of the climatic zones and of their characteristics. Let us turn for a few minutes to the question of climate and health—a subject which is surely of the greatest concern to man. From the earliest times people have sought in

atmospheric conditions an explanation of the occurrence of disease. Many fairly obvious facts naturally point to some relation of cause and effect in this matter. Some diseases are found principally in warmer climates; others seem to prefer the colder. Some are usually more active in the warmer, or the drier months; others have shown the contrary relation. High altitudes are free from some of the diseases which prevail near sea-level, and have certain favorable climatic characteristics long recognized in the treatment of disease. In the case of other diseases, again, altitude has no effect. Dry climates, especially deserts, whose air is usually exceptionally pure and aseptic, are generally healthful, and are beneficial in many cases where mountain climates are too stimulating. The climates within forested areas have proved especially favorable in cases of phthisis. Ocean air, pure and dust-free, with its saline constituents and equability of temperature, is beneficial to most persons as a moderate tonic and as a restorative in many illnesses. Winds are active ventilating and purifying agents where population is congested. Fogs and clouds, by cutting off sunlight, weaken one of the best agents in promoting health, for sunlight, in the words of Dr. Sternberg, is "one of the most potent and one of the cheapest agents for the destruction of pathogenic bacteria." In London, a higher death-rate follows a long fog, but this may result from the lower temperature during the fog, and not from any direct effect of the fog itself.

A Complex Subject.—Facts like these naturally prejudice one in favor of a causal connection between atmospheric conditions and disease. Nevertheless, such studies have often led to very contradictory conclusions. Some of the difficulty arises from untrustworthy statistics, but most of the disagreement comes from the fact that not only may each of the different weather elements have some effect in the production of the disease, but so many other factors are concerned in the matter that confusion and contradiction in the conclusions reached are inevitable. Sanitation, food, water, habits, altitude, character and moisture of the soil, race, traffic and other controls, serve to complicate the problem. In most studies of climate and health some, or even many, of these factors have not received attention. Overcrowding under unhygienic conditions, especially indoors during cold weather, and traffic by rail, steamship, caravan or on foot, are often more important than climate. The frequent escape of mountain, of desert and of polar peoples from epidemics is to be attributed in most cases to the smaller chance of importing disease because of little intercourse with the outside world, and of spreading it, when imported, because of the scattered population. It may be noted, however, that crowding indoors in winter, and the sparseness of population just referred to, are themselves climatically controlled.

Climate, Microorganisms and Disease.—The cause of disease is no

longer sought directly in meteorological conditions, but in the effects, more or less direct, of these conditions upon the microorganisms which are the specific cause of the disease. Atmospheric conditions may help or may retard the development of the microorganism, and may strengthen or weaken the individuals' power of resistance. Winds used to be regarded as the chief agents in spreading epidemics: now it is known that disease can not be carried far by winds, for the microorganisms do not long maintain their power in the free air and under the sun. Rain has been supposed directly to control the distribution of disease: now we believe that precipitation acts only indirectly, through drinking-water, or through its control over the dust in the air. Dust from dry soil, and from city streets, may contain the germs of infectious diseases, and aggravate affections of the respiratory organs.

Geographical Distribution of Disease.—The scheme of classifying disease geographically, on a broad climatic basis, is attractive, but not very satisfactory. For, on the one hand, many diseases are practically universal in extent, showing great independence of climate, and, on the other, the history of many diseases is still in the making. In spite of this complexity, however, certain broad statements may be made, useful in enabling the layman properly to coordinate his ideas on the subject, and fairly accurate within reasonable limits.

Tropics: General Physiological Effects.—Tropical monotony of heat is associated with high relative humidity, except over deserts and in dry seasons. The air is therefore muggy and oppressive. This "hot-house air" has an enervating effect. Energetic physical and mental action are often difficult, or even impossible. The tonic effect of a cold winter is lacking. These conditions have certain fairly well-established physiological effects, which, combined with less power to do work, greater fatigue from work, and lowered vitality, render the body less able to resist disease.

Hygiene in the Tropics.—Under the peculiar conditions of tropical climates, the resident who comes from a cooler latitude should take special precautions regarding his mode of life and personal hygiene. A rational, temperate life, especially the avoidance of alcoholic excess; regular exercise; non-fat-producing food; clothing suited to the climate; all possible sanitary precautions; protection against mosquitoes; frequent change of climate by returning to cooler latitudes—all these are important. It seems like a contradiction, but it is a fact, that the danger of becoming chilled in the tropics is very great and must be carefully guarded against. General Wolseley is reported to have said of the tropics, "not to get cold is to avoid almost certainly all the causes of disease," and a recent writer has well said that these words should be inscribed on the walls of all barracks in the tropics. The situation may be summed up in this rule: "Respect the sun, and

rain and wind; clothe with a view to avoiding chill; live temperately." On the Calcutta docks are painted the words: "Beware of the sun."

Tropical Diseases.—Certain diseases are so much at home in the tropics that they have come to be known as *tropical diseases.* This designation, however, does not mean diseases confined to the tropics, but is employed in a meteorological sense for diseases associated with, but not solely, or even necessarily directly due to, high temperatures. Sir Patrick Manson has made it clear that the difference between the diseases of tropics and extra-tropics lies in the specific cause of these diseases. For the development of certain disease germs, tropical temperatures are required; or a third organism, other than the disease germ itself and man, may be necessary. If this organism is a tropical species, as in the case of the tsetse fly, the disease is a tropical disease. "The more we learn," Dr. Manson says, "about these [tropical] diseases, the less important in its bearing on their geographic distribution, and as a direct pathogenic agency, becomes the *rôle* of temperature *per se,* and the more the influence of the tropical fauna." The fact that plague, and leprosy, and to some extent cholera as well, are practically limited to the tropics, is the result of modern sanitary precautions in the extra-tropics. The unsanitary conditions among tropical peoples favor the spread of these, and similar, diseases, and not the climate *per se.* Nevertheless, it is clear that these very unsanitary conditions are "more or less an indirect outcome of tropical climate."

General Conclusions: the Tropics.—All parts of the equatorial zone are not equally disagreeable or hostile to the white race. Many elderly persons, and those who are overworked, may find rest from nervous tension in the enervating climate of the tropics. Much-needed relief from the heat at sea-level may be obtained at tropical mountain stations, and many of these have become well-known health resorts. In India, the hill stations are crowded during the hot months by civilian and military officials, and it has been well said that India is governed from 7,000 feet above sea-level.

Acclimatization of the White Race in the Tropics.—The acclimatization of the white race in the tropics is a question of vast importance. Upon it depend the control, government and utilization of the tropics. It is a very complex problem, and it has been much discussed. It is complicated by race, diet, occupations, habits of life and the like. To discuss it fully is impossible at this time. The gist of the matter is this: white residents from cooler latitudes, on coming into the tropics, must adjust themselves physiologically to the new climatic conditions. During this adjustment there is more or less strain on various organs of the body. The strain may be too severe, then the individual suffers. The adjustment is usually much retarded and hindered by a persistence in habits of food, drink and general manner of living which, however well suited to the home climate, do not fit tropical conditions. Dur-

ing the adjustment, especially if complicated by irrational habits, the body is naturally sensitive to the new diseases to which it is exposed. Even should no specific disease be contracted, there are anæmic tendencies and other degenerative changes. Experience teaches that white men can not, with impunity, do hard manual labor under a tropical sun, but that they may enjoy fairly good health as overseers, or at indoor work, if they take reasonable precautions.

Acclimatization, in the full sense of having white men and women living for successive generations in the tropics, and reproducing their kind without physical, mental and moral degeneration—*i. e.*, colonization in the true sense—is impossible. Tropical disease and death rates, as has been abundantly shown, can, however, be greatly reduced by strict attention to sanitary laws. And with increasing medical knowledge of the nature and prevention of tropical diseases, as well as by means of modern sanitary methods, a white resident in the tropics will constantly become better able to withstand disease. For greater comfort, for better health and for greater success, properly selected hill stations will, however, always be essential to northerners who have to live in the tropics, especially to white women and children.

It has been well said that the white soldier in the tropics is "always in campaign; if not against the enemy, at least against the climate." This sentence may be made to fit the case of the white civilian in the tropics by making it read: the white race in the tropics is always in campaign against its enemy, the climate.

Health in the Temperate Zones: General.—In the temperate zones the organs of the body act more equally than in the warmer and cooler latitudes. The winter cold is met by means of warm clothing, heated houses and other means of protection. Unless too severe, or too prolonged, the cold winter acts as a healthful stimulant upon body and mind. In the tropics, the body is unused to adjusting itself to temperature changes, because such changes are there slight, and is readily affected by them. But the frequent, sudden and severe changes of many parts of the temperate zone are usually borne without serious discomfort or injury, if the body is in good health, and is accustomed to adjusting itself readily to these changes. The habit of keeping houses very warm in winter, and of having the air indoors very dry, weakens the body's power to resist the cold outdoors, especially if the air be damp, and aggravates affections of throat, lungs and nose. The summers, although hot in the lower latitudes of these zones, and marked by spells of warm weather even to their polar limits, are not characterized by such steady, uniform moist heat as is typical of much of the tropics. When the heat is extreme, and the relative humidity is high, night and day, sunstroke is occasionally noted, but the invigorating cool of autumn and winter are never far off, and may always be trusted to bring relief.

Winter and Summer Diseases of the Temperate Zones.—It is natural that such marked seasonal and such sudden weather changes as ours should be reflected in the character, distribution and frequency of the diseases which are found in these zones. Diseases of the respiratory system, bronchial and rheumatic affections, diseases that result from colds and chills, pneumonia, bronchitis, influenza, diphtheria, whooping cough, are all common in climates with sudden marked temperature changes, especially if these changes are accompanied by cold, damp winds. These diseases are also most frequent in the winter months, when the weather changes are more common and more severe, and when, in consequence, the vitality of the body is lowered and its power of resistance against the attack of the disease germs is weakened. A greater prevalence of diseases of the respiratory system, catarrhs and rheumatic affections in cool, moist weather, with sudden changes, has been shown by Weber, and several investigators have found a higher mortality after a greater variability of temperature. Many contagious or infectious diseases, such as diphtheria, influenza, measles and scarlet fever, for example, are also more common in the colder season, not because the lower temperatures are the direct controlling factor, but largely because the colder weather drives people indoors; houses and buildings generally are less well ventilated; more clothing is worn, less attention is paid to personal cleanliness and there is increased opportunity for contagion, especially among the poorer classes. Obviously, these are indirect effects of meteorological conditions.

In the warmer months, fevers and diseases of the digestive system, diarrhœa, malaria, typhoid fever, are prevalent. Thus there are usually two maxima of mortality: one in the colder season, when the changeableness of temperature is greatest, chiefly due to respiratory diseases, and another in the warmer months, largely due to infant mortality from disorders of the bowels.

Climate and Man: General.—Let us turn now to some larger, more general, relations of climate and man. Man's climatic environment affects him in many ways. His clothing, dwellings, food, occupations and customs; his physical and mental characteristics; his systems of government; his migrations; his history—all are affected to a greater or less degree.

Civilized man protects himself more or less successfully against unfavorable climatic features. Thus, there is a gradual transition from the primitive shelter made of branches of trees, of skins or leaves, to the permanent and highly elaborate modern building, which is both heated and cooled artificially. There is also a transition from the primitive and scanty clothing made of leaves or bark, where trees grow, or the skin of an animal, where trees are lacking, or where warmer clothing is needed, to the manufactured or perhaps imported garment of wool, cotton or silk. Again, there is the increasing variety of food,

from that of primitive man, supplied directly where he lives, to the highly varied diet found in a civilized community to-day, to which distant latitudes are made to contribute their local delicacies. Nowhere has man given a more striking exhibition of his ingenuity in meeting and overcoming, at least partially, the obstacles put in his way by climate than in his construction and operation of railroads. Transportation by rail is necessarily closely affected by climatic conditions, for trains have no protection against snow, wind or heat. The trans-Siberian railway was constructed with great difficulty because of frozen soil, spring thaws and upheaved tracks. Across the rivers and across Lake Baikal, rails were laid on the ice during construction times. Later, the trains were carried across the lake in winter on ice-breaking ferry-boats. The snow-blockades on the northern railroads of America led to the invention and use of the ingenious and effective rotary snow-plough, and to the construction of snow fences and of the highly interesting modern snow sheds, made in sections, which may be "telescoped" into one another in summer, in order to prevent the destruction of many miles of these sheds by fire. The campaign of a modern street railway system against the winter's snow is carefully planned in the previous summer, and a mild, open winter means a saving of money, time and labor, which results in increased earnings and larger dividends. The freezing of harbors at the termini of the northern railroads is a serious handicap in many countries. Russia's desire for an ice-free port at the terminus of the trans-Siberian railway on the Pacific led to her acquisition of Port Arthur, and ultimately to the war with Japan. The construction of railroads across deserts presents many difficulties. Ties dry up and twist; the danger from fire is greatly increased; fire patrols are often necessary; fuel is expensive and must be imported; water, for men and for locomotives, must be brought in by water-trains, tank cars or pipe-line; drifting sands cover the track and must constantly be shoveled off; the blowing sand hinders seeing, and increases friction and wear on the rolling-stock; watchmen are employed to guard against accidents from blowing sand on the track. A curious effect of sand-blasting is noted in the California desert, where the telegraph poles along the railroad are so worn near their bases by the blowing sand that they have to be protected by piles of stones. In the dense vegetation of the tropics, the roadway is constantly being overgrown, and men must be kept at work cutting down the weeds and underbrush. This involves great expense, and seriously reduces the earnings of the roads. Recently, tank-cars, which frequently spray the right of way with a strong poison, have come into use, as on the Guayaquil-Quito line in Ecuador, and elsewhere.

All this man has brought about in his combat with climatic conditions. But he can not change his climate. Slight local modifications may be secured here and there, as by planting trees to serve as wind-

breaks, or in the case of protection against frost by the use of "smudges," or screens, or fires, or by erecting lightning rods to guard buildings against the danger of being struck. Man can not make it rain; nor can he prevent hail from falling, nor can he change his climate by planting forests. No such modification is possible in man's climatic environment as has been accomplished on the surface of the land under human agency. The atmosphere is as essentially unalterable as it is all-pervading.

Some Old Views Regarding the Effects of Climate on Man.—It is, however, easy to go too far in calling upon climate to explain certain phenomena which we may otherwise find it difficult to account for. This was the mistake formerly made by many writers on this subject. The broad generalizations of Montesquieu, Voltaire, Hume, Buckle and others, furnish interesting reading, and contain much that is suggestive and instructive, but they usually carry us well beyond the range of reasonable probability. Even Hippocrates's observations on climatic controls are not without value to-day.

Factors in the Problem other than Climate.—To most of these older writers, climate meant more than it does to-day. It included much of what is now termed our whole physical environment. We must remember that we are dealing here with large, highly complex phenomena. Man moves readily from place to place, from climate to climate. His food, drink, habits, occupations; to some extent his physical and mental characteristics, change in consequence. Inheritance, intermarriage, environment, opportunities, soil and many other factors enter in to determine what changes individual man and the race as a whole shall undergo. Time is a very important element in the final result, for in time a gradual adaptation to new conditions takes place. Climate is but one of many controls, albeit a most important one, for it largely determines what many of the other factors, such as diet, customs and occupations, for example, shall be. The task of giving climate its proper place as a factor controlling the life of man as a whole is a difficult one, which can not be definitely and satisfactorily solved to-day—or to-morrow.

Climate and Habitability.—Climate determines where, as well as how, man shall live. It classifies the earth's surface for us into the so-called habitable and uninhabitable regions. The deserts of sand and the deserts of snow and ice, whether the latter be near sea-level or high up on mountain tops, are alike climatic, the former because of aridity, the latter because of cold. The only non-climatic deserts are recent lava flows. Where a soil is present which is not frozen much over half the year, and where there is reasonable temperature and sufficient rainfall, plants and animals are found, ranging from few and lowly forms where conditions are hardest and where all life has to be especially

adapted to these conditions, to the greatest abundance where conditions are most favorable.

Man is influenced by much the same controls as those which affect plants and the lower animals. From the highest latitudes he is excluded by cold. The highest altitudes are hostile both because of cold and of diminished pressure. The deserts of sand are uninhabited, or thinly populated, by reason of aridity. Forests, where rainfall is abundant, are unfavorable to a dense population. The trees must be cleared away before settlement is easy. The waves of civilization, as one writer has expressed it, beat up against the forest, but only with difficulty do they break through it. The equatorial forests of Africa; the densely wooded Amazonian provinces of Peru; the forests of northern Sumatra; the eastern forested slopes of Central America, left longest to the native tribes, while the western, more open, and drier slopes were first settled by white men, and are best developed—these are examples of the repelling effect of dense tree-growth where the advance of civilized man is concerned. Even the earlier American civilizations, the Aztec and the Inca, halted before forested areas. The Incas were almost as much hemmed in by the forests on the east as by the Pacific on the west. Travel through dense forests is difficult. Narrow paths, along which travelers move in Indian file, are the natural, and in fact the only, ways of communication, unless travel can be by boat. It requires no wide stretch of the imagination to see a connection between the method of carrying goods in the African forests, on the backs or heads of negro porters, and the slave trade, which sells the man who carried the goods as well as the goods. Many of the natives who secure the rubber from the Amazonian forests, or from those of the Congo, are to-day subjected to hardships which equal those of slavery.

Man is widely distributed over the earth's surface. The coldest place in the world in January is a large Siberian city, Verkhoyansk, while one of the hottest places in the world is Massowa, on the Red Sea, the capital of the Italian colony of Eritrea. But the life of man is harder here and easier there, according to climatic conditions, and the scarcity or abundance of plant and animal life.

Man is distributed in great belts around the world, corresponding roughly to the broad zones of vegetation, desert, steppe and forest, the limits of which are set by temperature and rainfall, but man is far more dependent on rainfall than on temperature. There are certain common conditions of life which affect the people who live in the same zone in the same broad, general way. This, as Ratzel first pointed out, means that there is a climatic factor at work to maintain differences between the people of different zones, in spite of the great movements which are constantly tending to produce uniformity. All the regions of sparse population are gradually being encroached upon by an invasion from their borders. Forests are being cleared, and replaced by

agricultural lands. Wheat and corn are replacing grass on the steppes, especially where irrigation can be practised. Deserts are being reclaimed here and there where water is available. The more civilized man becomes, the denser the population which the different parts of the earth can be made to support. From the wandering hunting and fishing tribes of the African forest or of the borders of the Arctic Sea, through the farming populations of the cleared forest and of the steppe, to the crowded industrial centers of the modern city, there is such a gradation. It is the story of a more complete to a less complete mastery of man by his environment.

But in spite of all that man can do, the larger climatic limitations persist. The Greenland desert of snow and ice, the Saharan desert of sand: these remain, deserts.

Primitive Civilization and the Tropics.—There are reasons for thinking that primitive, prehistoric man, in his earliest stages, when most helpless, was an inhabitant of the tropics; that he lived under the mild, uniform, genial climate of that zone, where food was easily obtained and protection against the inclemencies of the weather least necessary. There has been a belief that southern Asia, with its numerous bays and archipelagoes, was probably the cradle of humanity. Civilized man is believed by many to have appeared first on the delta formed at the head of the Persian Gulf by the Tigris and Euphrates rivers. Ancient civilizations seem to have developed in the drier portions of the tropics, where irrigation was necessary in order to insure abundant and regular crops, and where lived races more energetic and more hardy than those of the damper and rainier portions of the tropics, with more luxuriant vegetation. Within the tropics, the greatest progress later came, not on the damp lowlands, but on the less fertile plateaus of Mexico and Peru, where the Aztecs and the Incas made their marvelous progress in the drier, cooler and somewhat more rigorous climates over 7,000 or 8,000 feet above sea-level.

The Development of the Tropics.—Within the tropics, under the equatorial sun, and where there is abundant moisture, animal and plant life reach a very full development. Here are the lands which are most valuable to the white man because of the wealth of their tropical products. Here are the tropical "spheres of influence" or "colonies" which are among his most coveted possessions. It is in this belt that food is provided for man throughout the year without labor on his part; where shelter and clothing are so easily provided, and often so unnecessary, that life becomes too easy. Nature does too much; there is little left for man to do. The simplicity of life, so far as providing food is concerned, has been emphasized by writers almost without number. Captain Cook put the case very emphatically when he said that a South Sea Islander who plants ten bread-fruit trees does

as much towards providing for his family as does a man in northern Europe who works throughout the year.

In a debilitating and enervating climate, without the necessity of work, the man who inhabits the tropics not unnaturally lacks the will to develop himself, and also the will to develop the resources of the tropics. Voluntary progress towards a higher civilization is not reasonably to be expected. The tropics must be developed under other auspices than their own. As Professor John R. Commons has well put it: "Where nature lavishes food and winks at the neglect of clothing and shelter, there ignorance, superstition, physical prowess and sexual passion have an equal chance with intelligence, foresight, thought and self-control." The energetic and enterprising nations of the world have not developed under the easiest conditions of life in the tropics. As Edward Whymper's Swiss guide said of the natives of Ecuador: "It would be good for tropical peoples to have a winter."

The Labor Problem in the Tropics.—"What possible means are there of inducing the inhabitants of the tropics to undertake steady and continuous work, if local conditions are such that from the mere bounty of nature all the ambitions of the people can be gratified without any considerable amount of labor?" In these words, Alleyne Ireland well sums up the labor problem in the tropics. If the natives are, on the whole, disinclined to work of their own accord, then either forced native labor, which is contrary to the spirit of the times, or imported indentured labor, becomes inevitable if the tropics are to be developed. With few exceptions, and those where the pressure of a large population necessitates labor, effective development has been accomplished only where imported Chinese, Japanese or coolie labor has been employed, usually under some form of contract. Negro slavery began in the West Indies, under early Spanish rule, and its perpetuation was certainly in part aided by climatic controls. The best development of many tropical lands depends to-day upon Chinese or Japanese labor. It will be so in the Philippines.

With a large native class which is indolent, working intermittently for low wages, or which is bound under some form of contract, it follows that the native or imported laboring classes are separated by a broad gulf from the upper, employing class, which is usually essentially foreign and white. The latter class tends to become despotic, the former, servile. Marked social inequalities thus result, accentuated by the fact that the foreign-born white is usually debarred from all hard labor in a hot, tropical climate. White laborers are not likely to become dominant in the tropics for two reasons: first, because the climate is against them; and second, because the native is already there, and his labor is cheaper. White men are not doing the hard daily labor of India, of Java, of the Philippines, or even of Hawaii. They are directing it.

The Government of Tropical Possessions.—The government of European possessions in the tropics has thus far been determined chiefly by three considerations: (1) The general incapacity of the natives, through ignorance, or lack of interest, or their undeveloped condition, to govern themselves properly. (2) The fact that the white residents are generally comparatively few in number and are only temporarily in the country, to make money and then go home again. This white population is often composed chiefly of men—soldiers, officials, merchants, adventurers. There is little inducement to found permanent homes. (3) The marked class distinctions already referred to. These generalizations must obviously not be carried too far, but what has been said is in the main true. The white residents constitute a caste, and naturally become the rulers, the home government retaining general control, often by force of arms. The native population, although largely in the majority, may have little or no voice in its own government. This is clearly not a democracy. It thus comes about that the tropics are governed largely from the temperate zone; the standards, ideals, motives, come from another land. And where governed under their own auspices, as independent republics, the success has not been great. Buckle first strongly emphasized the point that hot countries are conducive to despotism and cold countries to freedom and independence; and James Bryce has recently clearly set forth the climatic control of government in an essay on "British Experience in the Government of Colonies."[2] The very Europeans who exercise the controlling power in the tropics, themselves tend to become enervated if they live there long; they lose many of the standards and ideals with which they started; they not uncommonly tend to fall towards the level of the natives rather than to raise the standards of the latter. The peculiar situation which may arise from the government of a tropical possession in which the white race does not become acclimated has been emphasized by Dr. Goldwin Smith in a recent discussion of British rule in India. He says:

> **British empire in India is in no danger of being brought to an end by a Russian invasion. It does not seem to be in much danger of being brought to an end by internal rebellion. Yet it must end. Such is the decree of nature. In that climate British children can not be reared. No race can forever hold and rule a land in which it can not rear its children.**

The future of tropical possessions and "spheres of influence" offers many problems of great complexity, the solution of which is largely controlled by the factor of climate.

Climate and Man in the Temperate Zones: General.—Intermediate in location, in mean temperature and in their physiological effects, the temperate zones, whatever was the condition in the past, are to-day clearly the center of the world's civilization, as they have also been the

[2] *Century*, March, 1899, 718–729.

scenes of the most important historical developments for several centuries. From the temperate zones have come the great explorers and adventurers of the past, and are coming the exploiters and colonizers of to-day. In the occurrence of the temperate zone *seasons* lies much of the secret—who can say how much of it?—of the energy, ambition, self-reliance, industry, thrift, of the inhabitants of the temperate zones. The monotonous heat of the tropics and the continued cold of the polar zones are both depressing. Their tendency is to operate against man's highest development. The seasonal changes of the temperate zones stimulate man to activity. They develop him physically and mentally. They encourage higher civilization. A cold, stormy winter necessitates forethought in the preparation of clothing, food and shelter during the summer. Carefully planned, steady, hard labor is the price of living in these zones. Development must result from such conditions. In the warm, moist tropics, life is too easy. In the cold polar zones it is too hard. Temperate zone man can bring in what he desires of polar and tropical products, and himself raises what he needs in the great variety of climates of the intermediate latitudes. Near the poles the growing season is too short. In the moist tropics it is so long that there is little inducement to labor at any special time. The regularity and the need of outdoor work during a part of the year are important factors in the development of man in the temperate zones. Where work is a necessity for all, labor becomes dignified, well-paid, intelligent, independent. Behind our civilization there lies what has been well called a "climatic discipline"—the discipline of a cool season which shall refresh and stimulate, both physically and mentally, and prevent the deadening effect of continued heat. On the other hand, a very long winter is about as unfavorable as a very long summer. If outdoor work is seriously interrupted, progress is retarded. It is not surprising to learn that the difficulty of keeping farm-hands through the long winter has in the past been a handicap in western Canada, and that it was urged against the abolition of slavery in Russia that it would be impossible, without some form of compulsion, to keep farm-hands through the winter.

Northward Movement of Civilization in the North Temperate Zone.—The gradual migration of the center of civilization away from the tropics, and the highest development of the human race, not where life is easiest, but in extra-tropical latitudes, are significant. "Slowly but surely," as Benjamin Kidd says,[3] "we see the seat of empire and authority moving like the advancing tide northward. The evolution of character which the race has undergone has been northwards from the tropics." From the Mediterranean region, where the world's civilization, its commerce and its power were long centered, westward through Spain and Portugal, the migration continued farther and farther

[3] "Control of the Tropics," 51–52.

north in Europe, until Holland, and then England, became the dominant power. From lands of more genial climates to lands of colder and longer winters, but also of the most active and energetic races, the migration has taken place.

Present-day Migrations in the Temperate Zones.—Within the north temperate zone especially, and also across from the north to the south temperate, vast, peaceful migrations are taking place, determined to no small degree by climatic considerations. From Europe and Asia to the United States alone, a million people a year are now migrating. These aliens have shown marked tendencies to settle where climate, soil and occupations are most like those of their old homes, although the fact that most of them land at one port on the eastern seaboard, the concentration of industries in certain sections, and other artificial controls, have operated very effectively to counteract and interfere with this tendency. Scandinavians, for example, have gone largely into the northwest; and in the future, unless steps are at once taken to prevent it, the southern parts of the United States will doubtless have a population predominantly of Latin blood. I say this although I am well aware of the very homogeneous "native" character of the southern population to-day, and of the high birth-rate among that population. Canada has grown slowly, partly on account of the repelling effect of her long, cold winters and her generally severe climate.

This migration within the temperate zone is peopling Canada, South Africa and Australia with the same stock as that which occupies the home-land of the British Isles. Therefore, institutions and government essentially similar to those at home are possible in these colonies of England beyond the seas. The case is very different in tropical climates, as has been seen. Russia will later be found to gain great strength from the fact that she has expanded eastward within the same zone. I think it was Leroy-Beaulieu who first pointed out what a unifying influence in Russia is the severe winter cold and the snowfall. In spite of the many factors which make for diversity and lack of coherence, there comes a great factor of unification in the possibility of continuous sleighing over those immense stretches of country, from north to south and from east to west, when the frozen rivers can be crossed without bridges and when the traveler, on his sledge, can journey straight across country to the farthest limits of the empire.

It is interesting to observe how immediately controlled by the special weather conditions or even one season these voluntary migrations may be. Years of sufficient rainfall and abundant crops in the United States are always followed by a large immigration. A failure of crops in Europe, whether it be of wheat in one country, or of fruit in another, or of potatoes in another, resulting from drought, or storms, or excessive rainfall, always promotes a larger exodus from the country con-

cerned. There is, furthermore, a considerable seasonal migration across the Atlantic. Thousands of Italians come to the United States in the spring, to work during the warmer months, when farm and outdoor laborers are in demand, and return to the milder climate of Italy for the winter. Similarly, there is a seasonal migration, also chiefly of Italians, to Argentina at harvest time.

In connection with these larger migrations, there is an interesting tendency westward, observable not only in the westward "course of empire," but in the advantages enjoyed, in the belt of prevailing westerly winds, by those who live in the western quarters of cities. The "west ends" are usually the most fashionable and the newest sections of these cities, while the quarters to leeward, the "east sides" and "east ends," are inhabited by the poorer classes.

The Continents and the Temperate Zones.—So far as the continents are concerned, in their relation to the zones, Europe is well situated, being almost altogether in the temperate zone, and open to the ocean on the west, so that nearly all parts of it are well watered.

Asia is an overgrown continent. Much of it is in the temperate zone, it is true, but the interior is so far from the sea that the climate is severe, and the rainfall very deficient. This condition of hopeless aridity is depressing in the extreme, and this region is prevented from becoming thickly populated, or important, on that account.

Most of Africa is within the tropics. Its plateaus will furnish areas not wholly unfavorable for white settlement. The southern part of Africa is just within the marginal subtropical belt of the south temperate zone. The same is true of Australia. Most of the latter continent is a trade-wind desert, and therefore hopelessly arid.

South America is, unfortunately for white occupation, widest within the tropics, while its southern portion tapers off into the temperate zone. As a future home for the white race, it offers much less attractive possibilities than it would were the continent narrow within the tropics, and broad to the south. Its western portion is peculiar in having the tempering influence of high plateaus in the interior, and of a cool ocean current along the coast.

North America is widest in the temperate zone. This is one of its greatest assets. It suffers from the extreme cold of its winters in the north, and from the rain-shadow effect of its western mountains, which gives the interior basin and part of the western plains deficient precipitation. The interior of North America has more favorable rainfall conditions than Asia, because our continent is narrower. The eastern portion of North America is freely open to the Atlantic and the Gulf of Mexico, and this condition is much better than is the case in Asia. Most of the United States is wonderfully adapted, climatically, to serve as the home of a dense population.

The Life of Man in the Polar Zones: a Minimum of Life.—In the

polar zones a "monotony of cold" replaces the "monotony of heat" of the tropics, and instead of the spur of the temperate zone seasons there is the depressing, long, polar night. There is a minimum of life. Plants are few and lowly. Land animals which depend upon plant food must therefore likewise be few in number. Farming and cattle raising cease. The reindeer, which manages to find sufficient food in the lowly Arctic vegetation, is the mainstay of the Arctic natives. But the reindeer must wander far and wide in search of their moss. And many reindeer are needed to provide sustenance for one man. Population is small, and scattered. There are no permanent settlements at all within the Antarctic Circle. In the Arctic, human settlements are fairly well scattered over a considerable range near the margins of the zone, but with increasing latitude man is more and more rarely seen, and finally he disappears altogether. There will never be permanent settlements at the poles.

Life is hard. Man seeks his food by the chase on land, but chiefly in the sea. Hardly one tenth of Greenland's population could live there without food from the sea. It has been well said that, with every degree of higher latitude, man is forced more and more to obtain his food from the sea. Gales, snow and cold, cause many deaths on land, and also at sea. It has been estimated that about one twenty-fifth of the population of Iceland perishes through being lost in snowstorms, by freezing or by drowning. The polar limit of permanent human settlements is believed by Bessels to be fixed, not by the decreasing temperature, but by the increase in the length of the night, which shortens the time during which man can lay up food, by hunting and fishing, to last him through the polar night.

Culture in the Polar Zones.—Under such adverse conditions it is not hard to see that progress towards a higher culture is not a reasonable expectation. There is little time in which man may seek to develop and satisfy his higher needs. Much truth is contained in Guyot's somewhat picturesque statement:

> **The man of the polar zones is the beggar overwhelmed with suffering, who, too happy if he but gain his daily bread, has no leisure to think of anything more exalted.**

A sparse population, not far advanced in culture or in social relations, is inevitable under polar conditions of climate.

Deserts of Sand and Deserts of Snow.—There is a singular similarity, in their relation to man, of the deserts of sand, near the equator, and the frozen deserts of snow, near the pole, to which I have referred. The relations are interesting, for they illustrate very clearly how similar climatic controls, acting through plant and animal life, affect the life of man in the same large way. I can not select a better example for closing my discussion this afternoon.

Deserts of sand and deserts of snow: both alike repel man. Both are largely or wholly destitute of vegetation, of wood and of water. The yellow desolate waste of the sand desert is matched by the monotonous white surface of the snow desert. There are no opportunities for accumulating wealth in either. Travel is difficult in both. In one, the camel is the typical beast of burden; in the other, the reindeer and the dog are man's most useful possessions. The monotonous heat and glare and silence of the sand desert find their counterpart in the cold, and glare, and silence of the snow desert. The air is generally clear in both, except for the dust over the sand desert and the ice-needles in the air of the snow-desert. In both deserts, man is very limited in his food supply: in the Sahara the date, in Greenland the seal, are typical staple articles of diet. The aridity in one, and the cold in the other, are man's great enemies. The inhabitants of both deserts are nomadic. Settlements of some permanency are found in oases or along the edges of the sand desert, where there is water; similarly, the natives of the far north live along the edges of the ice desert, where they can best find their food. The sand deserts are deserts because they are arid. The snow deserts are deserts because they are cold. Denudation of exposed rocks in the desert of sand is largely due to the action of wind, carrying sand; and denudation of the surfaces of ice in the desert of snow is due to the action of wind carrying ice spicules. The polar deserts are perhaps on the whole better suited to life than the sand deserts, for the former supply water from the melted snow and ice. Man has, however, a harder struggle to protect himself against the cold than against the heat, for he needs more clothing, and better shelter, and fire. In both deserts life is isolated and primitive. The sand desert is crossed by caravans and trade routes between the more populous lands on either side, and the people of these deserts have more contact with civilization than do most of the natives of the far north. The polar desert of snow and ice: who travels across it except the occasional explorer, seeking the Pole?

THE STRUCTURE OF THE WORLD-STUFF[1]

By Professor HORACE CLARK RICHARDS

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SCIENCE, and the humanities. How often are they placed in opposition. There is doubtless a utilitarian aspect of science which though admirable in itself tends to foster a spirit antagonistic to culture. But science is many-sided. And in the single-minded seeking for the truth amidst clouding obscurities, in the searching out the laws of the development be it of an atom, a tree, a man or a star, in the aim to express that unity which we instinctively feel is the key to the interpretation of nature's marvelous complex, I feel that she earns an honored seat among the immortals. And so I need make no apology for speaking to you upon a scientific subject, one which lies at the very basis of natural science, one whose development has demanded not only zealous, strenuous research but calm judicial, wise speculation,—the subject of the constitution of matter, the stuff of which the physical world is made.

The ultimate structure of the material world around us must always have been a problem of deep interest to thoughtful minds, and has formed a fruitful subject of speculation from the time of Thales to the present day. But it is not of the philosophical aspect of the question that I venture to speak. I can not claim to be a philosopher—save such a one as is characterized by Touchstone as a "natural philosopher"—but only a student of physics; and it is therefore to the physical side of the problem that I shall confine myself. The substance and the form of Aristotle, the monad of Leibnitz, the strife between idea and thing-in-itself, and other metaphysical contributions toward the interpretation of the universe, important though they be in the history of thought, are beyond the limitations of the present speaker and of the present occasion. Our attention is rather to be directed to the physical theories which have been framed as to the constitution of matter, especially to the one which has won almost universal acceptance, that known as the atomic theory; its development from the past, its modern form, and its promise for the future.

For the hypothesis of atoms is not a product of modern science. Indeed the question of the divisibility of matter must necessarily arise in the early stages of scientific thought. In our youth when we inquire as to the structure of things we are told that

> Little drops of water,
> Little grains of sand,

[1] Address delivered before the joint meeting of Phi Beta Kappa and Sigma Xi, University of Pennsylvania, June 16, 1909.

Make the mighty ocean
And the wondrous land,

and we doubtless speculate as to whether the sand grain and the water drop are not likewise divisible into smaller portions, and whether these smaller portions differ in quality from the larger. And so in the youth of science we find some philosophers maintaining the infinite divisibility of matter, and on the other hand the school founded by Leukippos and Demokritos, to whom we owe the conception and the word *atom*, the indivisible (or at least never divided) particle which forms the ultimate structure of matter. In these atoms, their ceaseless motion and their various groupings, is to be found the interpretation of the manifold phenomena of nature.

Both of these schools of thought have contributed to modern science. From the former we obtain the conception of a continuous medium which has developed into the theory of the all-pervading ether. From this school too we received the doctrine of the limited number of elementary substances from which all things are formed; a number which has grown from the four of Empedokles—earth, air, fire, water—through many vicissitudes into the eighty or so of the present day. But to the opposing school we owe a far greater debt, a debt which we can not lightly repudiate with Clifford by saying "The atomic theory of Demokritos was—no more than a guess—which was more near the right thing than the others." The atomic theory is much more than a guess. Incorporated into the system of Epikuros, and expounded in the marvelous poem of the Roman Lucretius, it forms a well-reasoned and well-balanced system of thought which it is true lacked in definiteness but was not without marked success in furnishing a framework on which to erect an image of nature. So successful was it that after two millenniums it has suffered little modification. As an illustration let us compare the atom of Lucretius with that of Newton.

These are the words of the Roman poet:

The atoms are of solid singleness, and, compact of smallest parts are closely coherent—not compounded from a combination of these parts but strong in their everlasting singleness; from these Nature allows nothing to be broken off or diminished; . . . very different are they in their forms; varied by manifold shapes.[2]

While the description by Newton is as follows:

It seems probable that God in the beginning form'd Matter in solid, massy, hard, impenetrable, moveable Particles, of such Sizes and Figures, and with such other Properties . . . as most conduced to the End for which he form'd them; and that these primitive Particles being Solids, are incomparably harder than any porous Bodies compounded of them; even so very hard, as never to wear or break in pieces.[3]

A comparison of these passages shows how the two conceptions are

[2] I., 609, and II., 333.

essentially the same. Indeed in some respects the older view has the advantage, as it lays greater stress upon the motion of the atoms; a forecast of the modern kinetic theory of matter.

The lack of development of the atomic theory is to be ascribed largely to the adverse criticism of Aristotle. The overwhelming influence of the Aristotelian philosophy was thrown against it, and it made little headway down through the middle ages. Not until the downfall of scholasticism do we find any extensive revival of the system; a revival culminating in the seventeenth century school of atomists, among whom are to be noted Gassendi, Boyle and, as we have seen, Newton. But still another century of stagnation was to elapse before it was to be transformed and modernized at one stroke by the genius of the English chemist John Dalton.

The modern atomic theory founded by Dalton and developed during the nineteenth century must not be regarded merely as an extension of the older theory, but as a new structure built upon the old one as a foundation. That was speculative, this was scientific. That was vague, this was definite. That was based merely upon observation and introspection, this upon experiment and calculation. The theory of the elements and the theory of atoms was blended into a single comprehensive whole. The prime distinction between the different kinds of atoms was found in a single property—that of their relative mass. The older theory was not inadequate in the early days of science; but it failed when the quantitative relations of phenomena were brought into prominence by the development of experimental methods; and such was the case when the principle of the indestructibility of matter was raised by Lavoisier from a philosophic dogma to a scientific truth, and emphasis was thus laid upon mass as the fundamental property of matter.

I need not detail to you the marvelous growth of the theory during the past century; how it met every demand made upon it by modern chemistry, and indeed inspired much of the development of that science; how, on the other hand, it has lent its aid to the progress of physics and especially how by the founders of the kinetic theory of gases,

> **the flaring atom streams**
> **And torrents of her myriad universe**
> **Ruining along the illimitable inane**

were marshaled to the defense of the great principle of the conservation of energy, and the science of heat was annexed to the domain of mechanics. Let me rather recall to you the salient points of the theory as held by the close of the century, for comparison on the one hand with the theory of the past and on the other with its developments in the future.

[3] Opticks, 4th edition, p. 375.

Matter, it is held, consists of minute indivisible particles or atoms, of which eighty-one different varieties are at present recognized. These correspond to the chemical elements, oxygen, carbon, sulphur, iron, gold and the rest, by the combination of which all other substances or compounds are found. The atoms of each element are exactly alike, while those of the various elements differ in mass. Thus atoms of sulphur are twice as large as atoms of oxygen, silver atoms are nearly twice as heavy as those of iron. The largest atom known—that of the rare element uranium—is over two hundred times as massive as the smallest, the atom of the elementary gas hydrogen, which is taken as the unit of comparison.

These atoms are indestructible and can not be converted into one another. However, they are not, like the atoms of Lucretius,

Solida pollentia simplicitate,

"strong in their solid singleness," but are of complex structure, capable of vibrating in many different ways. From the evidence of the spectroscope we learn that each kind of atom has its own modes of vibration and is distinguishable from others by these no less than by its mass.

While the atoms are the fundamental units they can not in most cases exist in isolation, but are drawn together by the forces of chemical affinity into groups which we call *molecules*. The atom bears to the molecule the relation of the letter to the word on a printed page. While the number of kinds of atom is limited, that of the varieties of molecule is practically unlimited, there being as many kinds of molecule as there are substances, or words in the chemical dictionary. The number of atoms in a molecule varies greatly. In a few exceptional cases the atom and molecule are identical. This is the case, for example, with mercury and with rarer gases of the atmosphere. These elements are the *a, I* and *O* of chemistry. The inorganic molecules with which we begin our chemical studies are appropriately words of one syllable, containing but a few letters; while some of the organic molecules, with their hundreds or even thousands of atoms, surpass even the creations of Aristophanes and would require the mouth of Gargantua to utter.

This distinction between atom and molecule is one of the most important characteristics of the theory. The atom it is often said is the unit of the chemist, the molecule of the physicist. To determine the relations of the atoms in the molecule is one of the problems of chemistry; while it is the task of the physicist to form from the interactions and motions of the molecules a consistent theory of physical phenomena. To be sure, the boundary between the sciences thus laid down is somewhat arbitrary, and we need not be surprised to find it often overstepped from either side. There is in fact a whole borderland occupied by troops of marauders who style themselves physical chemists or chemical physicists, according to their predilections, and

who make frequent raids impartially into either territory, usually carrying off rich spoils.

It is natural to inquire as to the size of these molecules and atoms of which we are thus assured the world is made. The question of the relative size is accurately answered by chemical analysis. We know, for instance, that the atom of oxygen weighs 15.88 times as much as that of hydrogen, and so on. But this gives no answer to the question as to the absolute size. It may seem that it would be impossible—even presumptuous—to attempt to estimate the size of particles which must be far beyond the reach of the most powerful microscope; but this has been accomplished. Time would not permit me even to outline the methods of wonderful ingenuity by which this problem has been attacked. The study of the laws of expansion of gases, the phenomena of the soap bubble, the action of the electric current, the blue of the sky, the settling of fine drops of mist or of specks of dust, these and other classes of phenomena have all contributed to the solution; and the evidence from such varied sources has been strikingly concordant.

Let me give you the results. Small indeed are these atoms, but not immeasurably small. So small that when they are expressed in ordinary units the mind shrinks from the attempt to grasp them. But the scientist is not limited to a single unit of measure. The geographer uses a mile, the carpenter a foot. The astronomer's staff with which he gauges the motions of the planets in their courses stretches from the earth to the sun; while in estimating the distances of the fixed stars the unit is the far greater distance traversed by light in a year. And so in the world of the little a convenient standard of comparison is the wave of light, some fifty thousand of which are contained in an inch, of the order of the thickness of a brightly colored soap bubble or of the smallest things that we can see with our best microscopes. Measured in these units, we find the diameter of a hydrogen atom to be about one two thousandth part of a wave of light, or, in our ordinary measure, a hundred-millionth of an inch. We hear much of millions, especially in the daily press, though perhaps we have but a vague conception of them. For example, we heard not long since of a celebrated fine of $27,000,000. If that fine had been paid, and paid in dollar bills, and the bills laid end to end, they would have reached from Maine to California. (I do not suggest this as a desirable method of laying out money, though we often meet with suggestions of even less merit; but to help in expressing the magnitude of the quantities with which we are dealing.) Now if each bill were replaced by an atom, and the line closed up, it would extend a quarter of an inch. Or we may express the result in another way: The diameter of an atom bears the same relation to that of a tennis ball that the

tennis ball does to the earth; and the masses are in about the same proportion. If we emulate Archytas,

numero carentis arenæ mensorem,

"the measurer of the innumerable sands," and estimate the number of molecules in even a drop of water, we obtain a result far beyond our powers of realization; a number requiring 22 figures for its expression. It is surely not to be reckoned among the least achievements of science that it has determined the order of this enormous quantity and has even made us reasonably certain of the first figure.

Such is the modern atom. It would seem impossible to penetrate farther into the details of so minute a structure, one too whose elements defied attack by physical and chemical agencies. It was felt, however, that a system based upon some eighty distinct kinds of primordial matter could hardly be an ultimate solution of the problem; and the suggestion was early made that the atoms are complex groups of a fundamental atom—possibly that of hydrogen, the smallest known. This hypothesis, suggested and supported by the fact that many atoms are very nearly exact multiples of the hydrogen atom in mass, has proved attractive to those who saw in the orderly succession of properties among the elements (known as the periodic law) indications that matter has reached its present state of multiplicity through some process of evolution. Similar indications were thought to be found by some in the study of the spectra of the stars. But these views were speculative, and direct evidence was lacking; and little light was thrown upon the subject until just before the close of the last century new lines of investigation were opened which greatly extended and modified our views as to the nature of the atom. This expansion was determined by the simultaneous development of the modern or what might be called the atomic theory of electricity, usually known as the electron theory.

That electricity, like matter, consists of indivisible units or atoms had long been suspected, since experiments of Faraday had shown that the quantities of electricity carried by atoms were always either equal to or exact multiples of a single charge—that carried by the hydrogen atom; and the term *electron* had been suggested as a name for the atom of electricity. As early as 1878 the great Dutch physicist Lorentz had based an explanation of the refraction and dispersion of light upon the presence in matter of equal discrete particles or atoms of electricity, and this hypothesis was afterwards developed into a complete framework of a theory of electrical and optical phenomena. But in the absence of experimental confirmation little attention was paid to these theories until the investigations to which I alluded brought the electrons themselves forcibly before the scientific world.

In 1897 J. J. Thomson was investigating the electrical discharge

in highly rarefied gases—the so-called kathode rays. These had been proved to be negatively charged particles, and were supposed to be atoms or molecules of the gas. Thomson showed that they were identical in their properties whatever was the gas used; and while he was not able to determine their mass nor charge directly he succeeded in measuring the ratio of their charge to their mass and showed that *either* their charge was much greater than the atomic charge, *or* the mass much less than that of an atom. Of these alternatives he chose the latter as the simpler and more probable—a choice justified by subsequent research. Later investigations showed that particles identical in properties were emitted from metals under the influence of light, and from incandescent solids. If we assume that the unit charge is carried by these particles the mass is calculated to be about an eighteen-hundredth part of that of a hydrogen atom. They are also shown to be enormously more concentrated, as their diameter is estimated to be only a few millionths of the atomic diameter.

Let us note as the result of these investigations three highly significant facts. First, that here we are presented with bodies smaller —much smaller—than atoms. Secondly, that from whatever source they are derived—gas, metal or hot lime—their properties are identical. Finally that they are associated with a definite charge of electricity, and that this charge is negative. Here is the electron, the atom of electricity demanded by the theory of Lorentz.

But what of the positive electron? Search for this has often been made, but the mass of the positively charged particles has always proved to be comparable with that of an atom. There are some indications that positive electrons may be identical with positively charged atoms of hydrogen or of the gas helium whose atomic mass is four times that of hydrogen; but for the present we can say only that positive electricity is never found dissociated from matter of atomic dimensions.

These conclusions received confirmation from two other sources. The year before Thomson's measurement of the electron marks the discovery of radioactivity and the beginning of the researches which speedily led to the discovery of radium and similar substances. The properties of the rays emitted by these substances were carefully investigated and it was proved that they consist partly of negatively charged particles identical with the electrons, and partly of positively charged particles having a mass equal to that of a helium atom.

The other confirmation to which I alluded, while less direct, penetrates even more deeply into the structure of matter. In this same year (1896) a minute effect of magnetism upon light, discovered by Zeeman, was shown to be completely concordant with the theory of Lorentz, and to lead to the conclusion that the light of a luminous vapor was due to negatively charged particles circling in or about the

molecules, of dimensions similar to those almost simultaneously discovered by Thomson. Later developments of optical theory stimulated by this discovery indicated the presence in molecules of positively charged particles as well, but that these were atomic in size.

Thus three independent lines of investigation have almost simultaneously converged to furnish a basis for a new theory of electricity, which we need follow only so far as it affects the theory of matter. Of the two kinds of electricity we find but one—the negative—that can be detached from atoms. We find the negative electron too as a constituent of the atom. The electron, whatever its source, is always the same, while the positive charge partakes of the varying nature of the matter with which it is associated. Emphasis is thus laid upon the electrons as forming the true electrical fluid, the positive electricity playing a subordinate part. According to this theory a neutral atom, which we know contains some electrons, contains also enough positive charge to exactly neutralize them. If one or more additional electrons become attached to it, it becomes negatively charged with the atomic quantity or its multiple. If, on the other hand, it loses some of its electrons, it becomes positively charged. The terms positive and negative have here exchanged their usual rôles. It is the positive electricity that is

der Geist der stets verneint,

"the spirit of negation." Except for this exchange (due to the unfortunate original allotment of the terms) the theory bears a remarkable resemblance to the single fluid theory of Franklin.

Some atoms normally contain too many electrons, others too few. These will attract each other, forming neutral molecules. Thus an oxygen atom, which normally holds two extra electrons, will attract to itself two hydrogen atoms which each lack one, and thus will form a molecule of water. By the number of electrons in excess or deficiency the combining power of an atom with others is determined. Such considerations have proved efficient in disentangling many puzzling questions connected with chemical combination.

The most salient point of this theory is that we seem to be confronted with a dualism, matter and electricity, atoms and electrons. A closer study of the electron has suggested a possible way of escaping this, or rather of turning it, in what is called the electrical theory of matter.

Long before electrons were observed J. J. Thomson had shown theoretically that a body when charged with electricity would by mechanical tests appear to have a slightly greater mass than when uncharged, and the smaller the body the greater the effect. Thus it would require more work to stop a moving charged body than if it were uncharged; a greater force would be needed to deflect it from its path. But even an

atom is not small enough for the difference between its charged and uncharged states to be appreciable.[4] With an electron, however, it is different. Application of the theory has shown convincingly that the entire observed mass of the electron may be accounted for by its electrical charge and that there is no evidence of any other mass apart from its charge. An electron is thus literally a disembodied spirit—a concentrated charge, and nothing more.

But what of the atom? We have seen that its mass can not be accounted for by its positive charge. We may, however, meet the difficulty in another way. Let us imagine a structure of the following nature. Scattered through the volume of a sphere of the size of our microcosmic tennis ball let us suppose a congeries of some 1,800 electrons. To get the scale of our image correct we shall have to magnify it still more and we shall then see this number of fine shot scattered through a space the size of a large hall. Let the equivalent neutralizing positive charge be uniformly diffused throughout the sphere. The electrical mass of such a system would be that of its electrons, in other words would be equal to that of a hydrogen atom. It is, therefore, unnecessary to attribute to such an atom any additional substance, "matter," distinct from the positive and negative charges.

This is the electrical theory of matter. I do not say that it has been established. It is at present only a fruitful speculation. But it strongly appeals to those who seek for unity in science and who prefer to have a single interpretation of a phenomenon rather than two separate hypotheses to account for the same thing. Some of the mass of atoms must be electrical. Why not all?[5]

Let us call upon the scientific imagination and attempt to picture the atom of the twentieth century for comparison with the atoms of the earlier theories. We see a large number of electrons immersed in what may be called a positive jelly. In some cases, if not in all, the atom is partly at least compounded of sub-atoms of the size of the hydrogen or helium atom. Of the electrons some may be vibrating about neutral positions, or circling in closed orbits, and in doing so sending forth waves of light; others may be more firmly fixed. We may even have systems of electrons revolving in concentric rings like the rings of Saturn. A few, especially if the atom is that of a metal, are so loosely attached that they readily escape, leaving the atom positively charged. Sometimes under the action of light-waves a vibrating electron is so violently shaken that it breaks its bonds and

[4] The electrical mass of a hydrogen atom due to its atomic charge is calculated to be about one hundred-millionth of its whole mass.

[5] It may be said that the dualism still remains. But it is now a dualism of form rather than of fact. Positive and negative electricity, like action and reaction, are but two sides of the same phenomenon. We can not have one without the other. But this would lead us too far into speculations as to the nature of electricity.

escapes. High temperature or a powerful electrical field may produce the same effect.

If our atom belongs to the group of radioactive elements such as radium, thorium, etc., we shall see from time to time, if we watch attentively, a kind of explosion. Perhaps an electron will be hurled forth with enormous velocity, perhaps one of the sub-atoms, sometimes both. The positively charged sub-atom, after it has given up most of its energy by collisions, will attract to itself a pair of neutralizing electrons and settle down, a staid helium atom. The remainder of the original atom rearranges itself into a new condition of more or less stability, and we have a new atom. It is no longer an atom of radium, for instance, but an atom of something else; another element with an atomic mass some four units less, and differing from radium as gold does from mercury. Its spectrum will be different; its properties will be different. It may perhaps be a gaseous atom instead of an atom of a solid. And we shall see this process continuing at irregular intervals, the atom gradually becoming smaller until a state is reached which is so stable as to seem permanent.—And all these processes are taking place within the bounds of our diminutive tennis ball.

Here we have the transmutation of the elements of which the alchemists dreamed. It is true that these changes now seem to go on "like the stars without haste without rest" uncontrollable by human agencies, but one would be rash to predict the impossibility of such control.

I have pictured a radioactive atom. But need we make that limitation? The intervals at which these transformations occur vary greatly. Thus we are told that the average life of a radium atom is about 2,000 years, that of its first product but four days, and a similar product of another element, actinium, lasts but a few seconds. It is estimated that an atom of uranium or thorium lasts some thousand million years, but still eventually changes into another form. In our imaginary picture we need set no limits to our measurement of time. The 200,000,000 years that we are told the earth has endured may be but a mere incident in the life of an atom; and an element surpassing uranium as much as that does some of the more rapidly disintegrating substances would appear permanent by all known tests.

The atoms would thus appear to be crumbling, perishing—indeed their death-knell has already been sounded. I find it in a recent number of a scientific journal.[6] I do not know the author, but the initials appended to it—W. R.—are those of the foremost chemist of England.

Old Time is a'flying; the atoms are dying;
Come, list to their parting oration:
"We'll soon disappear to a heavenly sphere
On account of our disintegration.

[6] *Nature*, **73**, 132.

"Our action's spontaneous in atoms uranious,
Or radious, actinious or thorious;
But for others, the gleam of a heaven-sent beam
Must encourage their efforts laborious.

"For many a day we've been slipping away
While the savants still doz'd in their slumbers,
Till at last came a man with gold leaf and tin can,
And detected our infinite numbers."

Thus the atoms in turn, we now clearly discern,
Fly to bits with the utmost facility.
They wend on their way, and in flitting, display
An absolute lack of stability.

'Tis clear they should halt on the grave of old Dalton
On their path to celestial spheres,
And a few thousand million—let's say a quadrillion—
Should bedew it with reverent tears.

But lest these views seem too somber and devoid of hope for the future, we must not forget that we may be looking at but one side of the mighty rhythm of nature. There may be also, still veiled from us, the compensating process by which atoms are formed and developed. This the author seems to feel and to express in his final verse:

There's nothing facetious in the way that Lucretius
Imagined the Chaos to quiver
And electrons to blunder, together, asunder,
In building up atoms forever.

The imaginative sketch of the atom which I have drawn must not be regarded as an accurate photograph. Many details are imperfectly known, many doubtless erroneous. But in its general outlines it reproduces the views of the foremost investigators, and it has proved eminently successful in unraveling the most extensive and perplexing body of facts that has ever been accumulated in so short a time.

But even when all difficulties shall have been smoothed away, and the electron enthroned above the atom, we shall not have reached the end. Even now we begin to hear discussions as to the shape of the electron, some holding it spherical, others flattened like the earth. There is, in fact, no final theory. "Every ultimate fact," says Emerson, "is only the first of a new series. Every general law only a particular fact of some more general law presently to disclose itself." We live in a succession of infinities. The earth with all its multiplicity is but a small part of the solar system; that is but an insignificant unit in a mighty stellar group. And so within the smallest sensible particle of matter is the world of atoms, within the world of atoms the world of electrons. Who shall set a boundary in the one direction or in the other?

THE RELATION OF THE LAW TO PUBLIC HEALTH

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PUBLIC interest in the preservation of health has generally found expression in a demand for legislation increasing the powers of governmental agencies charged with the protection of health. Boards of health, state and local, are more liberally sustained, have greater facilities for the investigation of disease and are armed with greater powers than heretofore, but nevertheless common law, that is, the great body of law which the colonists brought with them from England, has an important bearing on public health, chiefly in two ways. Without resort to statutes, means of protection are frequently available to the individual or to the community. On the other hand, unless in fact a common-law nuisance exists, boards of health are often, perhaps usually, powerless, either by reason of the express language of the statutes or because of the constitutional guarantees as to private property. The rules of the common law, therefore, as to nuisances, are fundamental to an understanding of the problems involved in safeguarding public health.

A variety of wrongs are classified as nuisances, which have little relation to each other and many of which have no relation to public health. In a general way, a nuisance may be said to be anything which wrongfully interferes with a public right or with the enjoyment of property. But stopping here, little progress has been made toward ascertaining what interferences are wrongful.

There are many things which render one uncomfortable which are not wrongful. A certain plaintiff was annoyed when his neighbor rented his property to an undertaker, but one has an absolute right to make any use he wishes of his property provided he does not create a nuisance, and the courts said that the plaintiff was unduly fastidious. So long as burial continues, some persons must be undertakers. It is annoying to be awakened in the morning by the roar of a city's traffic or by the crowing of a cock in the country, but such annoyances are necessary incidents to life in a given locality and must be endured. A case involving this principle arose in Philadelphia where a woman claimed that she was kept awake to the injury of her health by pneumatic riveting machines in a locomotive works. The inferior courts decided in her favor, prohibiting the operation of such machinery from eight P.M. to seven A.M., but the Supreme Court of Pennsylvania unanimously held that though there was no doubt inconvenience and dis-

comfort, such were the necessary incidents of life in a manufacturing neighborhood.

To constitute a nuisance, there must be a condition created or maintained by man. A swamp may be pestilential, but no one is responsible for the natural condition of land. Swamps are the work of nature and no matter how unhealthful they may be, any right to improve them must be sought in statutes.

In an early New York case the question arose whether at common law there was any right to remove a person with smallpox to a hospital. The court decided that if a man had smallpox, it was his misfortune and not his fault, and therefore announced that a person in his own house suffering from an infectious disease is not a nuisance.

Nuisances are classified as private and public. They are private when they affect private individuals. They are public when they interfere with a common right, such as the right to use a public street, or when they interfere with a considerable number of persons and thus take on a public character. The two classes run into each other. A public nuisance may be a private nuisance and frequently a private nuisance which could with difficulty be proved to affect the public may be ended by the enforcement of the private individual's right and thus the individual in helping himself may confer a great benefit upon the public in preventing the continuance of a dangerous condition.

Nuisances may be classified also in accordance with the nature of the injury done. Nuisances affecting health fall into two great classes. First, the pollution of flowing water. Second, the escape of deleterious things such as noise, smells, gases, disease germs, heat, electricity and vibration. The law is very different as regards these two classes.

One owning land along a stream is called a riparian owner and he has a right to the flow of the water in such stream in its natural purity undiminished, except by the ordinary domestic or agricultural uses of upper owners. If the quantity is substantially diminished or if the purity of the water is materially affected the lower owner may maintain an action without reference to the question as to whether he has suffered any actual damage or not. He may not have wished to use the water of the stream at all, but he is none the less entitled to use it. A single riparian owner then may be in a much stronger position to protect the community from stream pollution than a board of health or the community as a whole.

The commissioner of health of the state of New York has announced as his battle cry, "The continued pollution of our streams and lakes must stop."

The practical effect of a private individual's action in preventing pollution in contrast with the results of inaction by a community can be shown in the following cases. The report of the New York State

Department of Health for 1906 shows the correspondence relative to the pollution of a certain creek. On September 26, 1906, the state commissioner wrote to the president of the local board of health that numerous complaints had been made as to this creek, and that the state inspector had observed that seepage from cesspools found its way to the water. This letter was not answered. On November 14, the state commissioner again wrote. On November 26, the president of the local board replied that rules and regulations had been adopted, but as appears in a letter of December 17 from one of the four local justices of the peace nothing was done other than to post a printed copy of the rules. Cesspools and manure heaps continued to work, and on December 10 the president of the local board of health died of typhoid fever, while others in the town suffered from the same disease. The justice of the peace adds, "What we plainly need is some authority strong enough and courageous enough to order a thorough clean-up and see that it is done." In the other case the proprietor of a summer hotel situated on a brook above the plaintiff's land, discharged sewage into that stream. The local board of health had ordered such discharge to prevent the defendant from maintaining a cesspool, but this plaintiff, although she did not use the water of the stream for domestic purposes, but only for bathing and driving a turbine wheel, and although it appeared that the water was not affected either to sight or smell, was "strong enough and courageous enough" to fight the hotel proprietor in spite of the board of health. She won her fight in the trial court, then in the appellate division of the supreme court and finally in the court of appeals, and the discharge of sewage was forbidden. It might have been exceedingly difficult, perhaps impossible, to show that a public nuisance existed here, but the purpose of preventing stream pollution was accomplished by the riparian owner who defended her private rights.

The chief offenders in stream pollution are villages and cities, but the law is that such municipal corporations have no greater right than an individual to interfere with the riparian owner. There are numerous cases where actions have been maintained against municipalities, and in many of these cases injunctions have been issued. Where, however, the municipality constructs the offensive sewage system with statutory authority the private individual may ultimately fail in preventing pollution, for since his action is based not upon a claim that public health is interfered with, but merely that he is deprived of property rights, if the municipality has been granted the power of eminent domain, it can not be permanently enjoined if compensation is made to the private owner.

Most of the second great class of nuisances are those where the air has been contaminated, as by smoke, smells or gases. The law protects much more rigorously the right of a riparian owner to pure water than

to pure air. The water right is violated if there is any substantial pollution, but in the cases of air no nuisance exists unless the party alleging that there is a nuisance proves that he has actually been damaged. That is, not that he has been annoyed or inconvenienced, but that his occupation of the premises has been so affected that the comfortable enjoyment thereof has been interfered with. Such interference may result from a variety of causes, as smells from a slaughter house, noise from a boiler works, disease germs from a tuberculosis hospital, excessive heat from a neighbor's bakery, gaseous fumes from a brick kiln, or the vibration of heavy machinery.

When such interference is shown, it is no defense that the defendant's business is lawful or that the injury is unavoidable. The defendant may show that he is guilty of no carelessness in the conduct of a lawful business, that he uses the latest and best appliances and that his business is necessary to the community, but the courts answer that if one can not carry on this business without injuring his neighbors, he must carry the business on elsewhere or go into some other form of employment. This is an exceedingly difficult principle to apply. The business of slaughtering animals can not be made agreeable and yet it is necessary. Factories can not be carried on without smoke or noise. Some waste products usually result from any manufacturing business. While it may not be physically impossible to dispose of waste products by destruction, such destruction may be so expensive as to be prohibitive. A given concern may not be able to compete with its rivals if this added expense is put upon it, and so the sympathy of the courts and of the community may often be with the offender, but nevertheless such nuisances are not infrequently enjoined.

The case of the American Smelting and Refining Company against Godfrey was brought by four hundred and nine persons owning farms in Salt Lake County, Utah. They alleged that the smelters operated by the four defendant companies emitted one thousand tons of sulphur dioxide daily and also arsenical fumes, which destroyed their crops, poisoned their stock and injured the health of themselves and their families. The defendants showed that the location of their mines and the railroads made this place the most convenient for smelters and that they used the latest and best instruments to prevent the escape of obnoxious gases, but the court decided for the plaintiffs, saying, "You must not permit arsenic to escape and you can not smelt at this location any ores having in them more than ten per cent. of sulphur."

In many jurisdictions by the lapse of a long period of time one may acquire the right to do acts which would otherwise be a private nuisance, but it is held that one can not thus acquire the right to commit a crime, and therefore if a nuisance affects the public health and is thus a public nuisance, no prescriptive right to do such acts can be acquired.

Is it a defense to an alleged nuisance that the defendant was on the ground first? He may contend that he built his brick kiln, when all the surrounding land was vacant and thereafter the plaintiff voluntarily purchased and built on ground adjoining the kiln. This alleged defense is spoken of as "coming to a nuisance." Most of the cases, however, hold that this makes no difference. The injury arises only when the plaintiff's enjoyment is interfered with, but if he can not build a house, then the defendant would be in effect permitted to destroy the value of the plaintiff's property. If he must leave his land vacant it is worthless or at least its value is greatly impaired.

Assuming that the law is clear and that if the defendant is doing certain acts he is maintaining a nuisance, the plaintiff is always confronted by the necessity of proving by legal evidence that such acts are being done. This is often a difficult task. Ordinarily the defendant has large interests at stake and fights desperately to the last ditch.

The extent of the task of establishing by legal evidence the existence of a nuisance is shown in a recent case in which the question was whether one state could be enjoined from interference with the riparian rights of another state.

The state of Missouri brought suit against the state of Illinois to prevent the discharge of the sewage of Chicago by means of an artificial channel into the Des Plaines River, whence it entered the Illinois River and then the Mississippi. If this was a nuisance, by what law was it to be decided, that of Illinois or Missouri? The United States Supreme Court held that it could decide such controversies between states. Otherwise there would be no means of determining contests between states which in the absence of federation would be decided by war. But the court held that the rules applicable to private riparian owners did not necessarily apply between states and that the injury must be greater than a private injury to warrant relief. Missouri contended that the daily discharge of 1,500 tons of poisonous filth into this channel caused great injury to the public health in the state of Missouri since St. Louis and other cities took their water from the Mississippi River. Missouri showed that the number of deaths from typhoid fever had largely increased after the opening of the Chicago drainage canal. Missouri also showed by the presence in increased numbers in the Illinois River of the *Bacillus coli communis,* which it was agreed was an index as to the organic matter in the water, that the contamination was increased, but Illinois denied that injury to health had been caused, and so both sides conducted experiments to show the duration of life and capacity for travel of the *Bacillus typhosus.* It was conceded that typhus, cholera, dysentery, anthrax and tetanus are water-borne diseases and that it was practically impossible to discover the bacilli of typhoid in running water. It was proved by means of floats that the journey from Chicago

to St. Louis, 375 miles, required from eight to eighteen and one half days. Then Missouri caused 107 barrels of the *Bacillus prodigiosus* to be put into the drainage canal near the starting point on November 6. On December 4, one of these bacilli was found at the St. Louis Intake Tower, and a few others later. The duration of life of this bacillus in sunlight in living water, being alleged to be about the same as that of the *Bacillus typhosus,* it was urged that the typhus bacillus in the sewage of Chicago could reach St. Louis. But Illinois contended that typhoid bacilli could live only for three or four days, and so the representatives of Illinois suspended in the Illinois River, sacs which water could penetrate. In these sacs were bacilli of typhoid and in three or four days there were no living typhoid bacilli in the sacs. Illinois therefore claimed that they had died, to which Missouri replied that the constant change of water made conditions different, that these bacilli may have been of less than normal strength, or that they may have escaped from the sacs. On all the evidence the court held that it was not sufficiently clear that a nuisance existed and the bill was dismissed without prejudice to the right of Missouri to commence over again if it believed that it had evidence strong enough to prove its case.

If under the law, the alleged acts are a nuisance and if there is legal evidence to prove the facts, one additional question remains, that of procedure. What remedy is to be applied? The ingenuity of lawyers has been taxed to the utmost in devising remedies for nuisances. So difficult is it at times to succeed in ending a nuisance that the law provides as many remedies for nuisance, perhaps more remedies, than for any other form of injury, an entire arsenal of weapons, some public, some private, civil and criminal, judicial and non-judicial, legal and equitable, and sometimes all are required.

First there is the right of abatement. The law is jealous about permitting parties to remedy injuries with their own hands, but if the existence of a nuisance is clear, then one may himself put an end to it. The person who thus makes his own determination of right acts at his peril, and is liable if he has made a mistake. When abatement is threatened, if the case is doubtful the courts will forbid the use of this method, and unless there is pressing necessity, it should seldom be resorted to, particularly by private individuals.

The injured person may bring an action to recover compensation in money for his injuries and very frequently this remedy is selected. But as it does not put an end to the nuisance, it does not aid the cause of public health, unless the defendant voluntarily abates the nuisance through fear of further pecuniary loss.

The plaintiff may prefer to ask the court to prohibit the defendant from continuing the nuisance. Such relief is called equitable as distinguished from compensation in money, and this form of relief by injunc-

tion in equity is most effective, not only because it prevents threatened injury instead of operating upon harm which has been fully wrought, but in equity the defendant is required to terminate the nuisance under pain of punishment for contempt of the court's order. Frequently, however, at this point the controversy between the parties is hardly more than begun, for the form of injunction may be so indefinite as merely to prohibit causing material discomfort to the plaintiff or injuring his health, things which the defendant usually disavows doing from the beginning. The court struggles not to frame its injunction in such a way as to absolutely destroy the defendant's business, seeking rather some device by which the business may be continued without the accompanying nuisance, often a difficult and sometimes impossible task. The defendant may therefore succeed in having the injunction in so weak a form that it is ineffective, or he may after a period of compliance slowly resume the wrong doing, thus compelling the plaintiff to prove his case anew in contempt proceedings. While the private individual is thus seeking an injunction, the municipal body affected as to its property interest or as to its health, may as a matter of common law likewise procure an injunction.

Where the nuisance affects the right of the public, it is ordinarily punishable as a crime, and in some states abatement may be had by an order in the criminal proceedings.

Such is the law of nuisances relating to the public health. Laws do not execute themselves. A vigorous administration of statutory laws, adequate appropriations for the ascertainment and proof of the facts, enlightenment of the public mind as to the dangers from polluted streams and poisonous air, and a civic earnestness which not only will make easy the enforcement of law by public authorities, but will impel private individuals at some cost to themselves to set in operation the machinery of the common law, are all necessary. Many death-dealing nuisances await the attack of those who would protect public health.

INTERNATIONAL COINAGE

By THEO. F. VAN WAGENEN, E.M.

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IT is quite impossible to discuss the subject of coinage without touching that of money. But the reference to the latter will be brief, and will consist mainly of a statement of certain fundamentals that are now practically accepted by all.

The long and bitter controversy between monometalism and bimetalism has ended in an understanding that there is no such thing as "intrinsic value" in money. When gold monometalism became universal, silver took at once the status of a commodity, became subject to fluctuations in price according to the law of supply and demand, like all other commodities, and declined markedly in value as one of its former uses was curtailed by law. If the civilized world should agree that only certain kinds of clothing could be made of cotton, and that all others must be manufactured of wool; or that cane sugar must be the only kind employed for food, similar effects would take place in the prices of cotton and beet sugar. Again, as silver declined in price, silver mining became less profitable, and silver miners gradually forsook the business and turned their attention to gold. Immediately the production of the latter began to increase until at the present time its annual output is about double in value that of the combined product of silver and gold a generation ago. As this increase occurred, the value of gold declined, establishing the quantitative theory of the value of money. For, though by law an ounce of gold was still and is now, legally transformable at the mints of all modern nations into coin of a face or money value of about twenty dollars, yet the coins so produced and put into circulation have been capable of buying each year less and less of all other commodities; or, to put it differently, sellers of all commodities have each year demanded more money for their wares, that is, prices have steadily risen since the flood of gold began. Thus the commercial world is faced to-day with the same problem that was up for solution thirty years ago in the matter of silver, viz., how to render more stable the purchasing power of the money unit, in view of the enormous and rapidly increasing output of the world's gold mines.

Here a word as to the two metallic schools may not be out of place. Monometalism was (and is) based upon the theory that either one of the precious metals (but gold surely) is so rare in nature, so hard to win, and exists in such really limited quantities as compared with the

demand for coins, that if made by law the basis of money, it could be depended upon to exhibit permanent stability of value. Bimetalism, on the other hand, was founded upon the idea that in the development of the resources of the globe by man the discoveries of new sources of the two metals had, in the past, occurred in a roughly alternate sequence, would continue to occur so in the future, and that if both were admitted freely to unlimited coinage at an agreed ratio, based upon the proportionate tonnage output in the past, as far as records went, in the long run, through any considerable term of years, this tonnage ratio would be maintained. If so, the value ratio would be justified, and the two would float side by side. It was also held that the world needed both, because neither could be produced in sufficient quantity to meet the demand for coin. There was much in the way of historic fact to support these views. Considering only the era since the discovery of the new world, which is as far back as statistics on the subject are at all reliable, there was first the great output of gold from the Brazils, Venezuela and Colombia, which was followed by the silver flood from Mexico, Bolivia and Peru. Later came the almost simultaneous discovery of the Australian and Californian gold mines, after which occurred the vast silver output from the Nevada, Utah and Colorado silver deposits. But during the height of each of these metallic waves it became a strain on commerce to maintain the theoretical parity as based upon the average output, and because united international cooperation towards that end could not be secured, the effort was finally abandoned.

Since the civilized world became welded together by commercial ties as well as by railroad and steamship lines, the post office, the telegraph and cable, and now finally the telephone; as banks of deposit, discount and issue multiplied, and exchanges for produce as well as for stocks and bonds became fixities in all the great financial centers, the use of paper in the way of warehouse receipts, bills of exchange, checks, drafts, bank and government legal tender notes, has enormously expanded, so that among the wealthy and well-to-do the use of coin for money has already decreased almost to the vanishing point, and there is a positive dislike to a silver coin larger than an inch in diameter, and a decided preference to leave all gold coins in the custody of the banks, and use in place their notes and bills, or those issued by the governments. This is a perfectly natural evolution, and one that is bound to continue until the average citizen above the class of wage earner will carry only enough visible money to meet the spot cash necessities of the day, and will transact all the balance of his business with a check book. The process is already so far advanced that few people besides travelers and sports now-a-days carry upon their persons or in their homes the equivalent of more than five to ten dollars in money. What is to be

the outcome? Will all coinage ultimately degenerate to a mere matter of tokens? Will all other kinds of money disappear between the covers of a check book? Will bank vaults become in the end the only place where one can get a sight of one hundred dollars in coin at a time?

But even with the banks the same process is in progress. Vaults are steadily becoming smaller, and are being used more for the paper evidences of property than for coin, or even bills. In large cities the bulk of the money is kept at the clearing house. In countries that possess central national banks it is stored in their cellars or kept at the government treasury. Money, as money, is undoubtedly disappearing rapidly from view, and in its place is arising a system of credits and credit transfer agencies, capable of being used not only by the people of each nationality, but between the nations themselves. How far the process can go remains yet to be seen, but a realization of the advance to date will show the road along which the financial world is traveling, and give some idea as to the goal that may be ahead.

But as yet only a very small part of the inhabited world has become really civilized. The United States and Canada on our side of the Atlantic, northwestern Europe on the other side, Australia, New Zealand and parts of Japan, a little patch of South Africa, a few spots in Latin America, and small areas in eastern Europe and India. The balance of the inhabitants of the globe may be considered financial barbarians. In numbers they will outbalance us nearly ten to one. With them money (where it has advanced beyond the idea of shells, hides or cattle) is still coin. For bills they have yet no use. There are living nearly fifteen hundred millions of such people that are capable of earning an average daily wage of as much as twenty-five cents or more. If all could be set to work the weekly pay roll would be about two and a quarter billion dollars. Assuming a month as the time required for coins among this class to make the trip from earner around through the hands of merchants and banks back to employers, it would take ten billion dollars' worth of silver money to permit of the steady employment of this army of laborers. Of course between sixty and seventy per cent. of this mass of individuals would not be earners (the women, children, old and decrepit), but, on the other hand, the actual laborers would be paid from fifty cents to a dollar a day, according to capacity. Here then is a large field for the use of the metal that the civilized world is rapidly discarding. For silver only could be used, gold representing too much value. At its present market value of say $15,000 per ton, it would take nearly seven hundred thousand tons of the white metal to produce the above mentioned stock of coin. The present annual production of the world is a little less than 7,000 tons. Hence it would require the entire product at the present rate for the next one hundred years to supply the demand. In view of the large use the

western world yet has for small coin, and for silver in the arts, it will probably be safe to say that if the progress of civilization is not stayed, if it advances only at the rate that has obtained during the nineteenth century, there could be created a demand for the metal to the extent of the full output of the mines of the world at the present time, for probably the next two hundred years.

The question is, how to inaugurate and encourage this demand, how to introduce among the black and yellow men the coin of the white man, and interest them in its acquisition. Each in its way, the great commercial nations of the day are unconsciously engaged in the task. The English shilling is working northward from the Cape of Good Hope, has already come in touch with the German Mark and the Portuguese peseta which have been introduced on both the east and west sides of the continent, and will in due time meet the French franc and Italian lira coming south from the shores of the Mediterranean. In Asia, the Indian rupee, the Russian rouble, the Japanese yen and the American-Philippine coins are already competing for the patronage of the Malay and the Chinaman. In South America neither American nor European coins have any foothold, the Latin-American nations being well supplied by systems of their own, all related more or less closely to the coinage of Mexico or Portugal. Thus the plainly evolutionary task of pushing civilization into the uneducated parts of the world through commerce is as badly hampered by the different coins offered to the barbarian, as are the efforts of the evangelists to introduce Christianity by the existence of the various denominations and creeds. The church is beginning to appreciate the wastage in its efforts, and is trying to minimize it by combinations among the denominations having for their object to standardize Christianity, so to speak, by reducing tenet and dogma to the lowest possible terms. Commerce must do the same. The white man's coins must be standardized and simplified. If this can be accomplished, not only will the western nations be able to push their commercial influence much faster than now, but a new and immense field will be opened to the producers of silver, which should not only stay the decline in values, but restore it for a century or two to the position it held fifty years ago. This achievement in its turn should have the effect of checking the present flood of gold, which is already a menace to commerce, and which in another decade will certainly culminate in disaster to the world's financial system. For if silver mining should become as profitable as of old, by reason of a return of value to $1.30 per ounce, many who are now reluctantly engaged in the extra-hazardous business of gold mining will abandon it in favor of the much less hazardous one of silver production.

In looking over the field to devise ways and means to secure an

international coin, it would seem as if the harvest is almost ripe for the gathering, that much preliminary work has already been done, and that if the cooperation of America, England, France and Germany was arranged, the step would be easily taken. The French franc, under different names but identical in value, is the legal unit in Greece, Italy, Belgium, Switzerland and the French colonies in north Africa. The English have been agitating for fifty years the reform of their currency, appreciating how great a handicap it is in commercial competition, and are only awaiting a plan that can be put into effect without too serious a wrench to the national susceptibilities. The German Mark presents the greatest difficulty, for it is the business unit of sixty millions of intelligent and pushing people. To North Americans the dollar of course seems to be the most satisfactory money unit in existence. Canada and Mexico already have it, the latter, however, at the silver valuation. It differs but a few cents in nominal value from that of the units of most of the Central and South American nations except Brazil. As the dollar was originally a Teutonic coin (known as the Thaler), and the Mark is a unit of comparatively recent origin, it would seem as if the Germans should not object too seriously to take it up again, and they would carry with them the Scandinavians, the Hollanders and the citizens of Austro-Hungary, with whom they have intimate financial and commercial relations.

The franc (and also the Mark) seems too small a unit for these days of great fortunes and huge capital aggregations, and the pound sterling is too large. As the shilling is really the retail unit of the British Empire—except in Canada and India—and has very nearly the value of our quarter, but little difficulty could be experienced by England and her colonies in changing to the dollar and a decimal system. Altogether the way seems very clear to us, but national pride in a coin, and national habits of long standing, are difficult matters to overcome. Perhaps the best argument in favor of the dollar is the rapidly growing financial preponderance of the United States and North America in general in the commercial world. This in time will force the financiers of all nations to think, write and act in terms of dollars as well as of their own coins, if they intend to keep up with the procession of events. Just as the English language, by the spread and increase of English-speaking people, is likely to become in due time the vehicle of communication between business men all over the world, so the dollar, aside from its inherent good qualities as a convenient money unit, promises, by reason of the expanding population, trade and activity of the North American continent, to become each year better known and better appreciated, until its universal adoption becomes natural and inevitable.

Aside, however, from such an argument, which Americans can not

press strongly without wounding the national pride of other people, and especially of the Europeans, the international coin will come in a comparatively short time, just as will arrive the international postage stamp, which, by the way, is very badly needed. For the upper classes of all countries, the people who travel, and have to stand the nuisance and loss of changing their money at every frontier, the bankers and international merchants who have to cumber their accounts with the fluctuating item of exchange between commercial centers will insist upon it. All the European nations with the exception of Russia and Turkey are ready for the change, and when these reach the stage of real constitutionalism in their progress upward, they will be compelled to follow, being already deeply in debt to the French, English and Germans. Japan may be counted upon to acquiesce instantly in any unit agreed upon by the rest of the civilized world. That virile and open-minded people will at once perceive the advantage to themselves in their program of the commercial conquest of China. Their present unit, the yen, will not stand in the way, but will rather assist in the change.

Consider the increased force of the commercial assault on continental Asia and Africa and the other untamed areas of the globe of an international coin which the half-civilized and barbarous people of the globe found could be used in trading with any of the nations. Asia is called "the sink of silver." Scores of thousands of tons of the white metal in the guise of Indian rupees, Mexican dollars and other coins have disappeared during the last four hundred years among its teeming millions, and the drain still continues at the rate of about 3,000 tons per annum. It is the result of sheer force of numbers, coupled with patient industry and frugality. When these people awake fully from their sleep of centuries, and begin to produce and consume with something like the vigor of the western world, they will be capable of overwhelming it with their output of raw material. With what can they be paid? The balance of trade has remained steadily in their favor as far back as records go. We can only at first satisfy a small portion of their demand in goods, for their wants will increase slowly. They know of but one kind of money, namely, silver, and require that inflexibly. The western world has silver in abundance. It is a drug on the market. Why not prepare unitedly to let them have what they desire, and what we can so easily furnish, and at the same time put it in the form of a coin, which, when it became their unit, would guide them along the path of increasing consumption of those articles which they can produce, and in the production of which we can never hope to be able to successfully compete?

THE HUBBARD GLACIER, ALASKA[1]

By Professor LAWRENCE MARTIN
UNIVERSITY OF WISCONSIN

SOUTHEAST of Mt. St. Elias and the Malaspina Glacier, Alaska, in the fiorded upper part of Yakutat Bay, known as Disenchantment Bay, is the Hubbard Glacier. It is the largest ice tongue in this region, except certain tributaries of the great Malaspina glacier. It has a total *known* length of twenty-eight miles along the trunk glacier, exclusive of one broad tributary whose lower twelve and one half miles is all that man has ever seen, two other much narrower tributaries each twelve miles long, five other branches each over five miles in length and scores of smaller tributaries. This system of ice tongues (Fig. 1) has, therefore, nearly one hundred miles of valley glaciers larger than

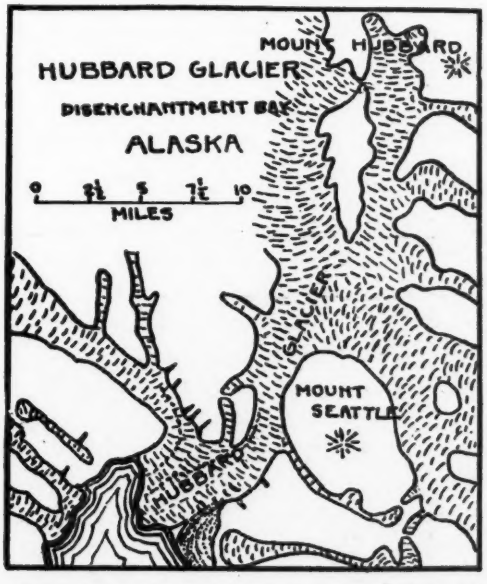


FIG. 1. Map of Hubbard Glacier and its known tributaries. The main glacier may rise at least twelve miles farther north, or over forty miles from the sea, while the northwest tributaries may be even longer.

[1] Published by permission of the Director of the U. S. Geological Survey. These observations are based upon (1) a U. S. Geological Survey expedition in 1905 under Professor R. S. Tarr, to which the writer was attached, his expenses being met by a grant of the American Geographical Society of New York, and (2) upon the National Geographic Society's Alaskan expedition of 1909, in charge of Professor Tarr and the writer. The illustrations are from photographs by A. J. Brabazon, of the Canadian Boundary Survey, Oscar von Engeln and the author.

FIG. 2. The Hubbard Glacier descending from its snow-fields to Disenchantment Bay. Mt. Hubbard, on the right, rises to 16,400 feet within twenty-five miles of sea-level, its slopes supplying large tributaries of the upper Hubbard Glacier.

the best-known glaciers in Switzerland, and the length of the upper parts of the three longest tongues is entirely unknown and the longest may exceed forty miles. No one of the tributaries as yet bears a name.

The Upper Glacier

The main glacier flows southward from the unexplored central part of the St. Elias Range past Mount Hubbard (Fig. 2), a beautiful 16,400-foot peak named, like the glacier, for Gardiner G. Hubbard, former president of the National Geographic Society of Washington. North of Mount Seattle the Hubbard Glacier has a width of three and one half miles and receives a tributary nearly two miles wide which rises twelve miles back on the slopes of Mt. Hubbard.

Another great tributary from the east, as wide as the main glacier, has its confluence just to the southward. These three ice tongues form the main upper glacier. It is near this confluence that civilized man has made his farthermost traverse upon the Hubbard Glacier. Several intrepid prospectors advanced this far up an adjacent glacier highway and over a snow divide to the Upper Hubbard Glacier during the gold rushes of 1898 and 1899.

The Lower Glacier

Below this confluence, the Hubbard Glacier is crevassed and entirely impassable, and moves down its valley imperceptibly, like the hour hand of a watch, in its irresistible progress to the sea. It descends southwestward over a broad step near the steeply-cascading glacier, shown on the map and in the photographs (Figs. 3 and 4), where it is joined by its longest tributary, the northwest arm. This tributary, two miles wide and at least twelve and one half and probably over twenty miles in length, rises on the slopes of Mt. Vancouver and joins the main glacier at right angles. The combined glacier, with a width of over four miles, advances into Disenchantment Bay in a sinuous cliff four and one half to five miles long and 250 to 300 feet high, one of the most magnificent in the world. Upon this lower glacier surface the Aletsch Glacier, the Rhone Glacier and the Mer de Glace of Switzerland might be placed without covering over two thirds of the lower Hubbard ice tongue.

The surface of the Hubbard Glacier is traversed by several prominent medial moraines. One of these comes from the northwest tributary and sweeps in a broad curve to the ice front. Another comes from near the west side of the main glacier. The east side of the Hubbard ice cliff is dark and debris-laden (Fig. 5) because this side of the glacier is covered with lateral moraine. The basal layers are filled with dirt and stones (Fig. 6) which perform the work of ice erosion. To the eastward this nearly stagnant border almost joins the entirely

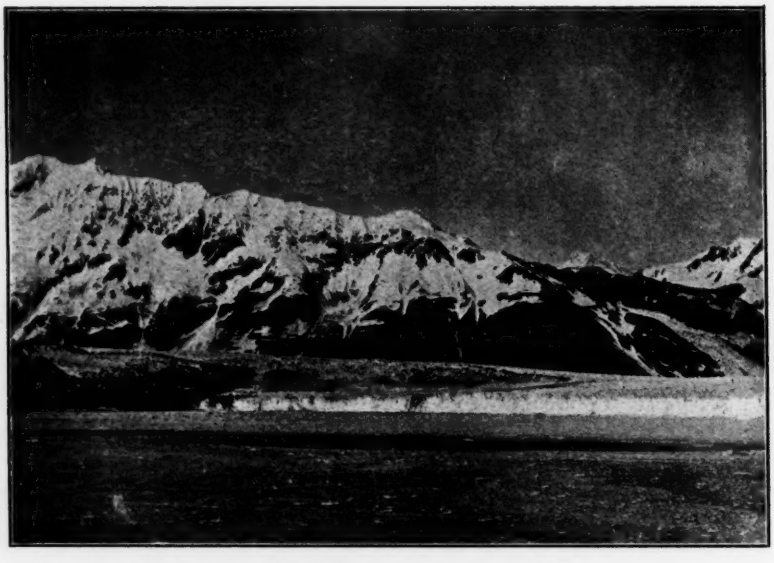


FIG. 3. West half of Hubbard Glacier, discharging icebergs into Disenchantment Bay. Mt. Hubbard in right background. Panorama with Fig. 4.

stagnant ice of the detached bulb of an adjacent glacier whose parti-colored crescentic moraines have led us to call it the Variegated Glacier. Ice underlies all this dark-colored area, however, where moraine mantles the quiescent and melting ice tongue in which there are numerous lakelets. The Hubbard Glacier is exceptional in having a small proportion of medial and lateral moraines, perhaps partly because it is so crevassed. Its surface is clear and attractive and its sea cliffs almost entirely snowy white.

THE ICE CLIFFS AND ICEBERGS

The foreground of berg-dotted fiord, the silvery ice cliff (Fig. 7), the sea of serac and crevasse behind, and the mountain background rising to 8,000 and 10,000 feet within ten miles of sea-level, form a scene never to be forgotten. One might not presume to too great familiarity with this lordly glacier, however, for an approach to within a half mile of the ice cliff, even in a seaworthy dory, means danger of capsizing in the iceberg-generated waves from the cliff or from overturning bergs. The formation of icebergs from the glacier as seen at safer distances is of fascinating interest. The dazzling white cliff (Fig. 8) with its tints of blue and green in the crevasses suddenly crumbles as if the foundation of one of the castellated ice towers were suddenly removed. Liquid silver seems to slip for minutes from the cliff, then a pinnacle falls with a crash. Instantly the water in front of the glacier, even if clear of bergs a moment before, is filled with white ice fragments, while blue and green and dirty-black icebergs, released from the submerged part of the cliff, rise through the pack of small bergs, casting

FIG. 4. East half of Hubbard Glacier, discharging icebergs into Russell Fiord. Mt. Seattle (10,000 feet) on right. Panorama with Fig. 3.

many of them into the air and overturning others. This causes a wave that splashes with lightning rapidity against the ice cliff and crunches in the ice caves there, while other waves spread ring-like across the fiord, overturning great icebergs on the way and causing the surf to splash spitefully on shores two and a half miles away for ten minutes or more. The accompanying noises were never absent at our camp facing the Hubbard Glacier. The stream of icebergs thus produced (Fig. 9) moves endless out toward the sea.

RETREAT OF THE HUBBARD GLACIER

This glacier, long known to the natives, was seen from a distance of about six miles by the searchers for the Northwest Passage, Malaspina and Vancouver, in 1792 and 1794. The former gave the undescriptive name of *Desangano* to this bay because of his disappointment at once again failing to find the passage. Before historic times the Hubbard Glacier extended southward more than thirty miles to the Pacific Ocean, receiving large tributaries on its way. In 1792 and 1794 it had probably retreated nearly to its present position, not being five miles down the bay as several have inferred.[2] When seen by the late Professor I. C. Russell, in 1890 and 1891, it was no doubt slightly farther back than in 1792 and 1794.[3] By 1899, when studied and

[2] See Tarr, R. S., and Martin, Lawrence, "Position of Hubbard Glacier Front in 1792 and 1794," *Bull. Amer. Geog. Soc.*, Vol. XXXIX., 1907, pp. 129–136.

[3] Russell, I. C., "An Expedition to Mount St. Elias, Alaska," *Nat. Geog. Mag.*, Vol. 3, 1891, pp. 90–100; see also "Second Expedition to Mount St. Elias," Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1892, p. 85.

FIG. 5. East margin of Hubbard Glacier, showing medial and lateral moraines and marginal lakes.

mapped by Messrs. G. K. Gilbert, Henry Gannett and the Harriman Expedition, it had retreated one or two hundred feet more.[4] Between 1899 and 1905, when the Hubbard Glacier was studied by Professor R. S. Tarr and the writer, the northwest side seemed to have advanced slightly and the southeast to have retreated.[5] That is, although continually advancing strongly, the glacier had extended its ice cliff farther into the fiord only about a quarter mile between 1891 and 1905, because ice was continually being discharged from the end in icebergs. Professor Tarr found very little change between 1905 and 1906, the west half having possibly advanced slightly.[6] It was about the same on this west side in 1909 (Fig. 10).

EFFECTS OF AN EARTHQUAKE

In September, 1899, however, this glacier, with the others in the region, was involved in an abnormal sort of experience which has notably affected its later history. This was a series of severe earthquakes.

Just east of the cliff of dirty ice shown in the photographs at the right of Hubbard Glacier (Fig. 11) there is a stagnant ice area which

[4] Gilbert, G. K., "Glaciers and Glaciation," Harriman Alaska Expedition, Vol. 3, 1904, pp. 63–66.

[5] Tarr, R. S., and Martin, Lawrence, "Glaciers and Glaciation of Yakutat Bay, Alaska," *Bull. Amer. Geog. Soc.*, Vol. XXXVIII., 1906, pp. 146–147.

[6] Tarr, R. S., Professional Paper 64, U. S. Geol. Survey, 1909, pp. 45–46.

looks black in the pictures and which forms the terminus of Variegated Glacier. Where the streams emerge from this area, eight men were washing the gravels for gold and platinum, their tents being near the base of the moraine-veneered gravel hills. Several earthquakes were felt by them upon September 3, 1899, and on the intervening days till September 10, when there was so severe a shock that seismographs recorded it throughout the world. Other earthquakes followed until September 29.

These prospectors tell us that on September 10 the ground shook and cracked and undulated, that waves washed up on the shore, small glacial ponds broke and caused floods, that the Hubbard Glacier crashed and roared, and that its front was broken instantly. The hundreds of ice towers shaken down at once and the great quantities of enormous icebergs released from beneath the sea by the shaking of the submerged part of the ice cliff so filled the bay that it seemed to them as if the glacier itself advanced half a mile into the fiord.

The men subsequently escaped with their lives and the glacier seemed in 1905 to have recovered from its loss. Its better-known neighbor, the Muir Glacier, 150 miles southeast in Glacier Bay, and other ice tongues there, however, have had a period of retreat initiated by this earthquake shaking in 1899 which has destroyed much of their scenic interest and removed nearly a mile of ice a year from their cliffs for the past eight years.

In Yakutat Bay, however, these earthquakes of 1899, which were

FIG. 6. Black ice of Hubbard Glacier margin laden with dirt and stones of basal ice. Such ice as this performs work of glacial erosion.

accompanied by faulting and by a 47⅓ foot uplift of the coast six miles southwest of Hubbard Glacier, a 17½ foot uplift 4½ miles south of it, a 7½ foot uplift four miles east of it, and a depression of the coast in some other places resulted in another sort of change. The prospectors encamped beside the Hubbard Glacier tell us of the great roar of avalanches during and after the shocks in 1899. In 1906 Professor Tarr found that several glaciers in this region had advanced a mile or more since we visited them the autumn before (Fig. 13). Only one had so advanced between 1899 and 1905. He has

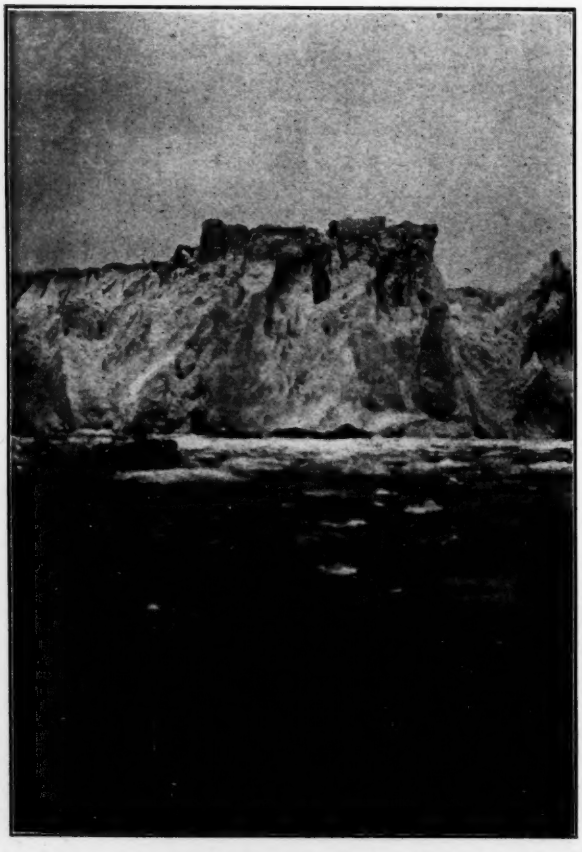


FIG. 7. The ice cliff of Hubbard Glacier, between 250 and 300 feet high.

shown this advance to be due to great avalanches which supplied abnormal quantities of snow to the heads of the glaciers during the earthquakes, resulting, after a delay of several years, in a spasmodic advance. The glacier shown on the map on the right and that on the left of Hubbard Glacier, advanced thus between 1905 and 1906 (Fig. 13). The Hubbard Glacier was unchanged in 1906. It may yet respond to a similar impulse imparted by this glacier flood and advance far into

FIG. 8. A view of Hubbard Glacier from above Osier Island in 1905. Severely crevassed, with few medial moraines. Icebergs are continually floating away from this cliff and are swirled by the tide into fantastic streamers.

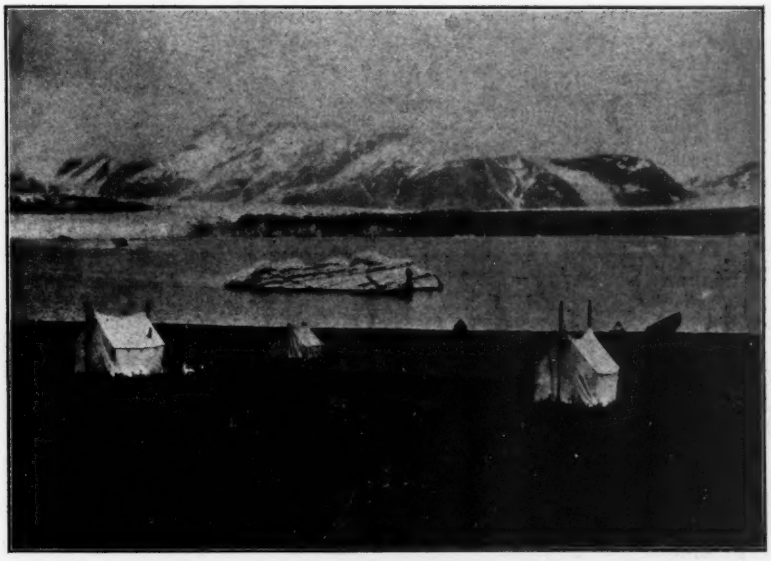


FIG. 9. An iceberg from Hubbard Glacier floating in front of our camp in Disenchantment Bay in 1905.

FIG. 10. The Hubbard Glacier from Osier Island in 1909, and essentially as in 1905 for the western portion of the front. It has had a net advance of at least a quarter mile since photographed from the same site by Professor Russell twenty years before.

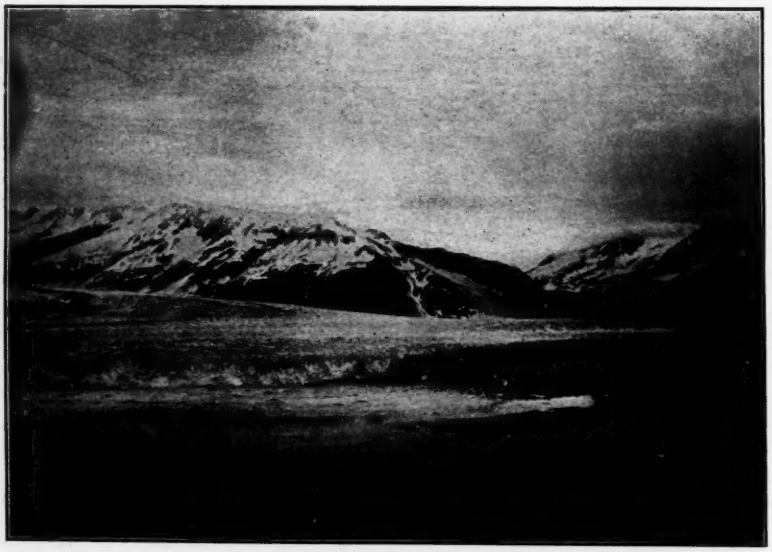


FIG. 11. East margin of Hubbard Glacier where ice advance was beginning in dark cliff in 1909.

Disenchantment Bay. If avalanches were not abundant enough, however, along its tributaries it may not feel this impulse at all. In any event it will continue to be, as it now is, one of the grand spectacles of nature, and worthy of the visits of appreciative men.

Beginning of Advance

The last paragraph was written in December, 1908. During the summer of 1909 the National Geographic Society's Alaskan Expedition, in charge of Professor R. S. Tarr and the writer, observed what seems to be the beginning of the advance predicted above, which has been

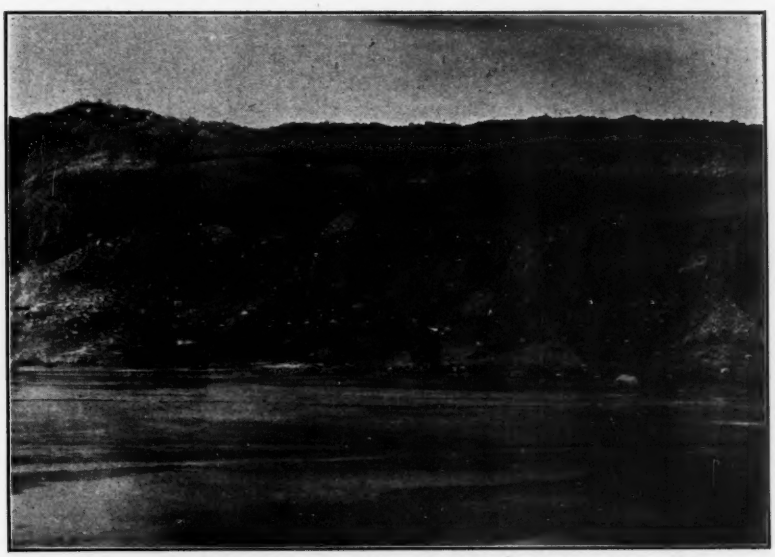


Fig. 12. Dark cliff of eastern Hubbard Glacier pushed up through ablation moraine between 1905 and 1909, and marking the beginning of the advance.

more fully described elsewhere.[7] The stagnant, dark-colored ice shown on the extreme right in Fig. 11 was resuming activity. Breaking had commenced, ice blocks were being pushed up through the morainic cover, as is shown in detail in Fig. 12. Stones were sliding down the surface and revived streams were burying willows growing near the ice front. A renewal of activity was in progress, but how great an advance there may be will not be known till studies can be made in the summer of 1910.

An adjacent ice tongue, the Hidden Glacier, advanced over two miles between 1906 and 1909. If the south side of the Hubbard Glacier advances a mile and half, however, it will override Osier Island once more (Fig. 13). This would change Russell Fiord southeast of the Hubbard Glacier from an arm of the sea to a fresh-water lake

[7] *National Geographic Magazine*, Vol. XXI., January, 1910.

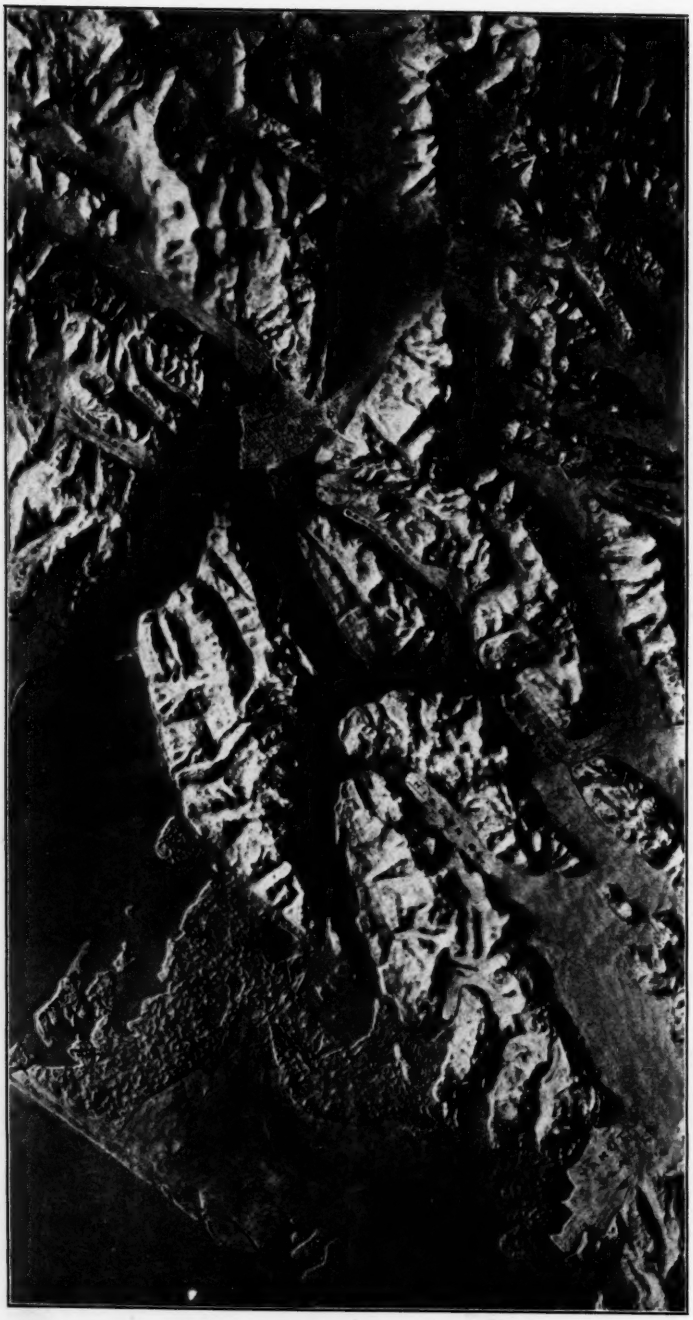


FIG. 14. Model showing the relation of Hubbard Glacier to bifurcation of Disenchantment Bay and Russell Fiord, branches of Yakutat Bay. A slight advance will convert Russell Fiord into a long, narrow lake, draining southward across Yakutat Foreland and probably receiving icebergs from Nunatak, Hidden, Variegated, Hubbard, and other Glaciers.

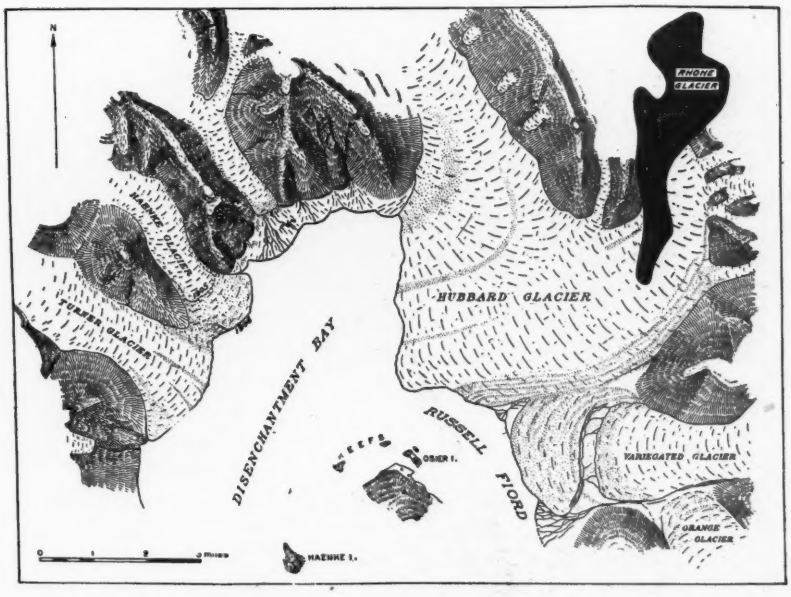


FIG. 13. Map of the lower fifth of Hubbard Glacier and adjacent ice tongues (after Gannett, Harriman Expedition, and Rich, U. S. Geol. Survey). The whole Rhone Glacier in Switzerland is drawn in black on exactly the same scale for comparison. The hitherto stagnant Variegated Glacier (on the right) and the Haenke Glacier (on the left) became crevassed and advanced between 1905 and 1906, the front of the latter moving nearly a mile in less than nine months and becoming tidal. In 1909 it once more ended on the land. A slight continuation of the advance of Hubbard Glacier would separate Russell Fiord from Disenchantment Bay and the Pacific Ocean.

(Fig. 14) which would be 33 miles long and 100 square miles in area. Its surface would be higher than the present fiord and would receive icebergs from four or more great glaciers, only one of which is now tidal. What would happen to the stagnant, moraine-veneered terminus of Variegated Glacier is a problem. The glacial lake would drain to the Pacific independently until future retreat of Hubbard Glacier resulted in the restoration of the lake to the fiord.

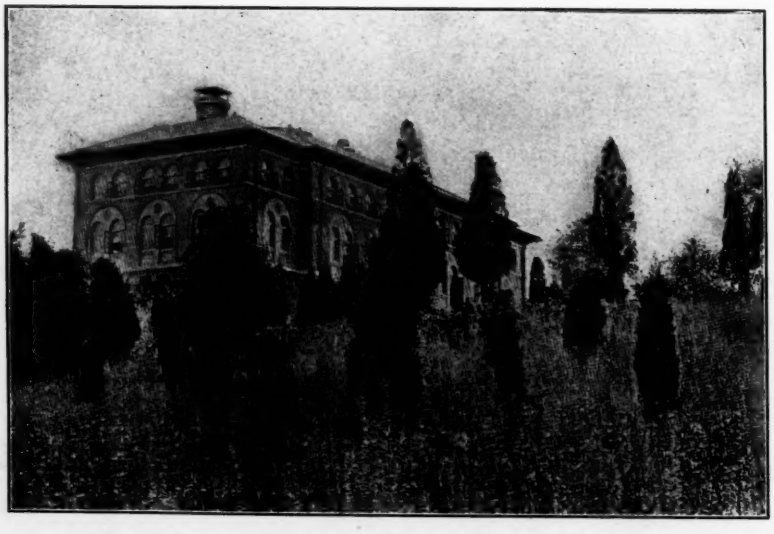
This renewal of activity by Hubbard Glacier is, therefore, of more than ordinary interest, especially as the advance is one of the type now well proved to be due, not to climatic variation, but to excessive avalanching during earthquakes.

THE PROGRESS OF SCIENCE

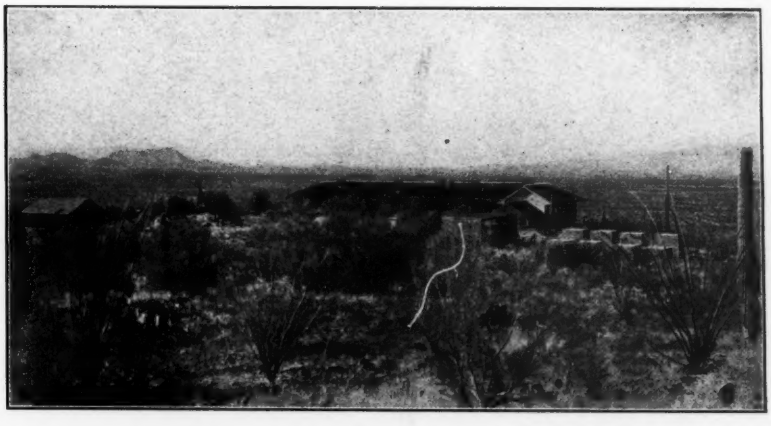
THE WORK OF THE CARNEGIE INSTITUTION

THE eighth year book of the Carnegie Institution of Washington gives an account of its activities during the past year. The appropriation amounted to about $650,000—about $467,000 being for the maintenance of its departments; $50,000 for minor grants; $30,000 for research associates and assistants; $54,000 for publication, and $50,000 for administrative expenses. As indicated in the last issue of the MONTHLY, the administration building was dedicated in November. No new department was inaugurated during the year, but the observatory for meridian astronomy at San Luis, Argentina, began its work under the direction of Dr. Louis Boss, of the Dudley Observatory, Albany. The Nutrition Laboratory adjacent to the Harvard Medical School was also for the first time in working order. The magnetic ship *Carnegie* made its first voyage. A new tower telescope, 150 feet high and extending 75 feet below the ground, has been begun at the Solar Observatory on Mt. Wilson, California. The work of the Geophysical Laboratory, of the Department of Botanical Research, the Cold Spring Harbor Station and the Marine Biological Laboratory at Tortugas were continued. During the year nineteen volumes were published containing 4,907 pages.

The scientific men who are working in the departments of the Carnegie Institution are accomplishing a great amount of valuable research; but it is not certain that the contributions from the United States have been increased to the extent that might have been hoped from the expenditure of four million dollars. All the leading officers of the institution were engaged in scientific work before its establishment, and it is a question whether their work is better than it would have been if they had remained in their previous positions. The places which they held have been filled by others and there is



THE GEOPHYSICAL LABORATORY, UPTON STREET, WASHINGTON.



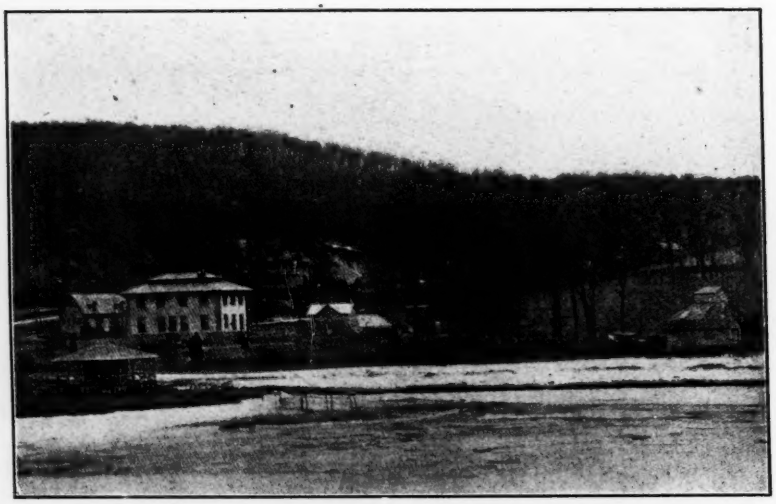
MAIN BUILDING, DESERT LABORATORY, TUCSON, ARIZONA.

thus opportunity for more workers. But the difficulty in the United States appears to be a lack of men rather than a lack of positions or of equipment. Those employed by the Carnegie Institution are somewhat isolated in their research stations and their influence in attracting men to research work and training them to it is less than it would be at the universities.

University professors have positions which should make the scientific career attractive to young men of ability and purpose. The associations of the university are on the whole pleasant and honorable. With his colleagues, his assistants and his more advanced students the professor has a stimulus to good work and opportunity to make it effective. As a rule the position is a life appointment; there are pensions, vacations and sabbatical leaves of absence. Yet, in spite of these attractions, it is difficult to find men of distinction for university chairs. It may be that they are not being born in sufficient numbers, but it is more likely that they are not found. The comparatively small salaries and the somewhat unsatisfactory methods of university control may be partly responsible. Whatever the difficulty may be, the pressing need of the present time is to find men: providing positions and equipment is scarcely of use except in so far as this may attract men.

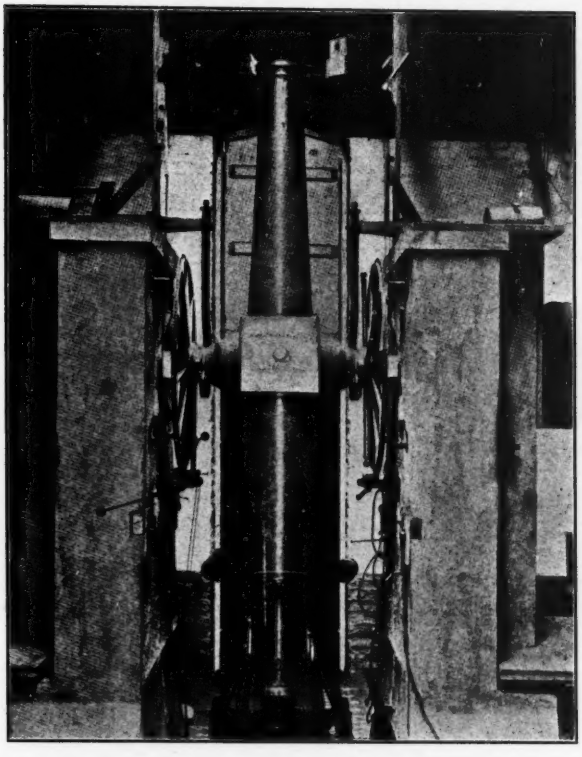
The Carnegie Institution has taken men from universities and from other institutions; it has not made new men of science or attracted men to scientific work. This it might have done by giving opportunity to men who could not otherwise find it, or by paying such salaries and conferring such privileges on scientific men as would make the career attractive to the best men. The salaries paid are not made public, but they are probably as small as will obtain and retain the men that are needed. The bureaucratic or department store system, which is the chief danger of the university, is in the case of the Carnegie Institution carried to an extreme, for the collective sentiment of a group of scholars, which is the balance wheel of the university, is there absent. It may be impossible for such an institution to accomplish more for science than it is doing, but certainly the official statement of its plans published eight years ago appeal more to the imagination. It reads:

It is proposed to found in the city of Washington, in the spirit of Washington, an institution which, with the cooperation of institutions now or hereafter established, there or elsewhere, shall, in the broadest and most liberal manner, encourage investigation, re-



GENERAL VIEW OF STATION OF DEPARTMENT OF EXPERIMENTAL EVOLUTION, COLD SPRING HARBOR.

MAIN BUILDING, TORTUGAS LABORATORY



TRANSIT-CIRCLE, SOUTHERN OBSERVATORY, SAN LUIS, ARGENTINE REPUBLIC.

search and discovery, encourage the application of knowledge to the improvement of mankind; provide such buildings, laboratories, books and apparatus as may be needed, and afford instruction of an advanced character to students whenever and wherever found, inside or outside of schools, properly qualified to profit thereby. Among its aims are these:

1. To increase the efficiency of the universities and other institutions of learning throughout the country, by utilizing and adding to their existing facilities, and by aiding teachers in the various institutions for experimental and other work, in these institutions as far as may be advisable.

2. To discover the exceptional man in every department of study, whenever and wherever found, and enable him by financial aid to make the work for which he seems specially designed, his life work.

3. To promote original research, paying great attention thereto, as being one of the chief purposes of this institution.

4. To increase facilities for higher education.

5. To enable such students as may find Washington the best point for their special studies to avail themselves of such advantages as may be open to them in the museums, libraries, laboratories, observatory, meteorological, piscicultural and forestry schools and kindred institutions of the several departments of the government.

6. To insure the prompt publication and distribution of the results of scientific investigation, a field considered to be highly important.

These and kindred objects may be attained by providing the necessary apparatus, by employing able teachers from various institutions in Washington and elsewhere, and by enabling men fitted for special work to devote themselves to it, through salaried fellowships or scholarships, or through salaries, with or without pensions in old age, or through aid in other forms to such men as continue their special work at seats of learning throughout the world.

PETER LESLEY.

THE LIFE OF PETER LESLEY

THE life and letters of Peter and Susan Lesley have been edited by their daughter, Mrs. Mary Lesley Ames, and published in two volumes of considerable size by Messrs. G. P. Putnam's Sons. The biography and the letters are largely personal in character. They are documents of human interest in depicting the lives of two superior and attractive personalities in their relations to the social conditions of New England and Philadelphia during the larger part of the last century. They also throw some light on the history of science in this country.

Lesley was born in Philadelphia in 1819 of Scotch presbyterian stock and dedicated to the ministry. His health being broken at the age of nineteen he obtained a place as assistant in the newly-organized geological survey of Pennsylvania, in order that he might have outdoor work for a season. Thus he was drawn to geology almost by an accident, as indeed it may be held that the comparatively considerable contribution of America to geology during the last century was a by-product of the development of our natural resources. Lesley completed his theological studies at Princeton, studied in Germany at a time when this was unusual, became a missionary in the

forest counties of Pennsylvania, and for three years had charge of a church in Milton, near Boston. There he was married and there he returned to live in his old age. But he was not sufficiently orthodox for the ministry and was fortunately driven back to geology.

In Philadelphia he became a geological and mining expert. He made maps of coal fields for the Pennsylvania Railway and compiled an iron manufacturer's guide. He was for many years secretary and librarian of the American Philosophical Society and in 1872 became professor of geology in the University of Pennsylvania. In 1874 the second geological survey of Pennsylvania was inaugurated and Lesley accepting the directorship carried out the great work of his life, though begun at the age of fifty-five years. The hundred and twenty volumes of the reports of the survey are due to the men he selected for the work, to his constant oversight, and to his careful editing. The work gives him high rank among those who have done most to advance geology in this country.

Lesley's interests were wide, being by no means confined to geology. He himself says in a letter to Professor O. N. Rood "I have done nothing worthy of record in science." He then tells what he believes his services to have been—improvements in certain instruments—the odometer, the measuring divider and the aneroid barometer; the introduction of contour curves in geological field work; and two theories—the determination of the present system of surface drainage by the dimpled form of the plicated original surface and the production of modern topography chiefly by the underground solution of limestone strata.

PETER AND SUSAN LESLEY.

In 1893 Lesley's health failed and he lived quietly until his death in 1903 at the age of eighty-four years. The photograph which his friends regard as the best is here given, and a reproduction of a portrait painted in the old age of her parents by Mrs. Bush-Brown.

SCIENTIFIC ITEMS

WE record with regret the deaths of Dr. Friederich Kohlrausch, the eminent

German physicist, of Dr. William Bradley Rising, professor of chemistry in the University of California, and of Dr. William George Light, formerly professor of geology at Denison University and the University of New Mexico.

A NATIONAL testimonial to Commander Robert Peary was held at the Metropolitan Opera House, New York City, on February 8. Governor Hughes presided and a telegram was read from President Taft which expressed the hope that congress would take some substantial notice of Commander Peary's great achievement. Governor Hughes presented Commander Peary with a purse containing $10,000, which he immediately contributed toward fitting out an Antarctic expedition.—The Langley medal of the Smithsonian Institution, created in 1908 in commemoration of Professor Langley and his work in aerodromics, was presented to Messrs. Orville and Wilbur Wright on February 10. Dr. Alexander Graham Bell and Senator Lodge made addresses and Chief Justice Fuller presented the medals.

A STATUE of the late Morris K. Jesup, for many years president of the American Museum of Natural History, was unveiled in the foyer of the museum on February 9. Addresses at the unveiling were made by Dr. Henry Fairfield Osborn, who has succeeded Mr. Jesup as president of the museum, and Mr. Joseph H. Choate, one of the founders of the museum.

A DEPARTMENT of experimental biology has been organized in the Rockefeller Institute. Professor Jacques Loeb, of the University of California, has been elected head of the department.—The Geological Society of London has awarded the Wollaston medal to Professor W. B. Scott, of Princeton University.—The French Academy of Moral and Political Sciences has elected Professor William James, of Harvard University, a foreign member of the society, in the room of the late M. de Martens, of St. Petersburg. Professor James has been a corresponding member of the academy since 1898.

THE late Darius Ogden Mills, of New York City, has bequeathed $100,000 to the American Museum of Natural History, $50,000 to the New York Botanical Garden and $25,000 to the American Geographical Society of New York City.—The Sheffield Scientific School of Yale University has received from Messrs. George G. Mason and William S. Mason $250,000 for a laboratory of mechanical engineering.